Desert Tortoise Recovery Plan Assessment

(*Working Draft, March 15, 2004*)

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Dedication

This report is dedicated to our colleague and friend David Morafka.

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Acknowledgements

There are too many people to acknowledge in this draft. We will assemble a fuller acknowledgement section in the next draft.

1. Introduction

1.1 Recovery Prescriptions in the Recovery Plan of 1994

The passage in the text box below is as it was written in the recovery plan of 1994. This is the core of what needs to be compared with current management and knowledge. The comparison we present in this document is meant to be a scientific evaluation of the Recovery Plan in relation to contemporary knowledge of (a) the biology of desert tortoise, and (b) the extent to which the recovery plan was implemented.

"The desert tortoise was listed as threatened primarily because of a variety of human impacts that cumulatively have resulted in widespread and severe desert tortoise population decline and habitat loss. The destruction, degradation, and fragmentation of desert tortoise habitat and loss of individual desert tortoises from human contact, predation, and disease are all important factors in the decline of the Mojave population If the desert tortoise is to be recovered within its native range, the causes of the decline must stop, at least within the DWMAs. Some factors are likely more important than others; for instance, urbanization has probably caused more habitat loss than light cattle grazing. *However, eliminating all factors that are deleterious to desert tortoise populations will certainly result in faster recovery than will selective elimination of a few*.

Accomplishing the prescribed recovery actions is needed to reduce or eliminate human-caused impacts in the recovery units and to implement the recovery strategy described in the Recovery Plan.

1. Establish DWMAs and implement management plans for each of the six recovery units

a. Select DWMAs

b. Delineate DWMA boundaries

i. Reserves that are well-distributed across a species' native range will be more successful in preventing extinction than reserves confined to small portions of a species' range.
ii. Large blocks of habitat, containing large populations of the target species, are superior to small blocks of habitat containing small populations.
iii. Blocks of habitat that are close together are better than blocks far apart.
iv. Habitat that occurs in less fragmented, contiguous blocks is preferable to habitat that is fragmented.
v. Habitat patches that minimize edge to area ratios are superior to those that do not.
vi. Interconnected blocks of habitat are better than isolated blocks, and linkages function better when the habitat within them is represented by protected, preferred habitat for the target species.
vii. Blocks of habitat that are roadless or otherwise inaccessible to humans are better than blocks containing roads and habitat blocks easily accessible to humans.

c. Secure habitat within DWMAs.

d. Develop reserve-level management within DWMAs.

e. Implement reserve-level management within DWMAs.

f. Monitor desert tortoise populations within recovery units.

i. Develop monitoring plan
ii. Implement monitoring plan

2. Establish environmental education programs.

a. Develop environmental education programs.

b. Implement environmental education programs.

3. Initiate research necessary to monitor and guide recovery efforts.

a. Obtain baseline data on desert tortoise densities both inside and outside of DWMAs.

b. Develop a comprehensive model of desert tortoise demography throughout the Mojave region and within each DWMA.

i. Initiate epidemiological studies of URTD and other diseases.
ii. Research sources of mortality, and their representation of the total mortality, including human, natural predation, diminishment of required resources, etc.
iii. Research recruitment and survivorship of younger age classes.
vi. Research population structure, including the spatial scale of both genetic and demographic processes and the extent to which DWMAs and recovery units conform to natural population subdivisions.

c. Conduct appropriately designed, long-term research on the impacts of grazing, road density, barriers, human-use levels, restoration, augmentation, and translocation on desert tortoise population dynamics.

d. Assess the effectiveness of protective measures (e.g., DWMAs) in reducing anthropogenic causes of adult desert tortoise mortality and increasing recruitment.

e. Collect data on spatial variability of climate and productivity of vegetation throughout the Mojave region and correlate this information with population parameters (e.g., maximum sustainable population size, see Appendix G).

f. Conduct long-term research on the nutritional and physiological ecology of various age-size classes of desert tortoises throughout the Mojave region.

g. Conduct research on reproductive behavior and physiology, focusing on requisites for successful reproduction."

1.2 Desert Tortoise Recovery Plan Assessment Committee (DTRPAC)

The original desert tortoise recovery team recognized the importance of including new data and analyses for tortoise recovery efforts as they become available. Indeed, the recovery team called for the recovery plan to be reassessed every three to five years to ensure that recommendations to management were made with the best available scientific information (FWS 1994, p. 37). Since the recovery plan's publication in 1994 there have been no overt efforts to revise the plan in light of new information pertinent to desert tortoise recovery, despite the fact that there has been new research on many aspects of desert tortoise ecology, threats, conservation biology, and monitoring, as well as public challenges to the validity of the plan.

The DTRPAC has reviewed the recovery plan, assembled contemporary reports with new knowledge, and assessed the efficacy of the recovery plan in light of the new knowledge. The DTRPAC was purposely assembled with scientists and experts diverse in terms of gender, State representation, institutions of employment, and scientific expertise. Some members were chosen who are not doing research on desert tortoise. The committee was assembled with representatives with the following characteristics:

1. academic scientists with expertise and experience with desert tortoise and/or ecosystems containing desert tortoises,
2. USGS scientists with expertise and experience with desert tortoise and/or ecosystems containing desert tortoises,
3. agency biologists with experience with the desert tortoise,
4. scientific specialists familiar with conservation biology and with expertise important to the DTRP evaluation process,
5. "internal peer-review" scientists serving as general science analysts whose job it will be to keep tortoise scientists from becoming myoptic while focusing on new data, analyses, and opinions for desert tortoise,
6. representatives of the original recovery team,
7. representatives from FWS, and
8. broad representation from the geographic range of the listed species

The committee included the following members:

C. Richard Tracy (Ph.D.), [Chair of the Committee] Professor of Biology, University of Nevada, Reno (Member of original Desert Tortoise Recovery Team, expert in ecology of reptiles and amphibians)

Roy Averill-Murray, Biologist, Arizona Game and Fish Department (Desert tortoise expert, manager of Arizona Desert Tortoise)

William Boarman (Ph.D.), Biologist, USGS/BRD (Bird biologist who studies ravens as predators of desert tortoise)

Dave Delehanty (Ph.D.), Assistant Professor of Biology, Idaho State University (Avian ecologist, expert on repatriation experiments)

Jill Heaton (Ph.D.), Assistant Professor of Biology, University of Redlands (Geographer/biologist, researcher of desert tortoise habitat needs)

Jeff Lovich (Ph.D.), Biologist, USGS/BRD (Turtle expert, author of the"Turtles and Tortoises of North America")

Earl McCoy (Ph.D.), Professor of Biology, University of South Florida (Ecologist with experience with gopher tortoise, philosopher of science regarding method in ecology)

Phil Medica, Biologists, USFWS (Desert tortoise expert, FWS liaison representative)

Dave Morafka (Ph.D.), Research Associate, California Academy of Sciences (Member of the original Desert Tortoise Recovery Team, expert on neonatal tortoise biology, expert on head-starting programs in bolson tortoise.)

Ken Nussear, University of Nevada, Reno (Ecologist of reptiles, expert on translocation of desert tortoise)

Bridgette Hagerty, University of Nevada, Reno (Desert tortoise ecologist, DTRPAC manager)

The committee reviewed the recovery plan to determine which parts required a more thorough analysis. The committee determined that new knowledge may have caused several parts of the original recovery plan to require modification. The topics reviewed included:

1. Distinct Population Segments (DPS) in relation to the Recovery Units designated by the original recovery team. Delisting criteria pertinent to each DPS (?).
2. Regional status of (a) populations and demography, (b) impacts to tortoise populations and habitats, (c) recovery plan implementation.
3. Specific threats and their mitigations with special attention to impacts resulting from interactions among individual threats. The relationships among threats and the importance of disease.
4. Monitoring of (a) desert tortoises, (b) impacts to desert tortoise populations, and (c) habitats.
5. Research needs and priorities in the next decade. Assessment of research proposed in 1994 DTRP and what remains needed.

To conduct the topic reviews most efficaciously, the committee invited outside experts to help conduct the reviews. This effectively expanded the panel of experts to very large numbers thus providing the expertise needed to conduct an extremely thorough review of the recovery plan. The outside experts participating included:

- Dr. Elliott Jacobson, DVM, Tortoise disease expert
- Dr. Mary Brown, Ph.D., *Mycoplasma* expert
- Dr. David Rostal, Ph.D., Tortoise reproduction specialist
- Dr. David Thawley, Ph.D., Veterinary epidemiologist
- Dr. Kristin Berry, Ph.D., Desert tortoise biologist
- Dr. Barry Noon, Ph.D., Conservation biologist/endangered species
- Dr. Michael Reed, Ph.D., Conservation biologist/population modeler
- Dr. Jim Sedinger, Ph.D., Population ecologist/population enumeration
- Dr. Chuck Peterson, Ph.D., Herpetologist/reptile ecologist
- Dr. Mary Cablk, Ph.D., Remote sensing expert
- Dr. Ron Marlow, Ph.D., Clark County HCP
- Ann McLuckie, M.S., Red Cliffs Reserve
- Ray Bransfield, CDCA Plan Amendments
- Dr. Bryan Manly, Ph.D., Statistician, consultant for user groups

FWS also invited diverse stakeholders to send representatives as observers to the committee meetings. Some of those representatives contributed substantively to discussions or report preparation and review. Others included:

- Ann McLuckie, Utah Division of Wildlife and Fish
- Clarence Everly, Consultant for the Department of Defense
- John Hamill, Department of Interior and Desert Managers Group
- Rebecca Jones, California Department of Fish and Game
- Karen Phillips, U. S. Geological Survey
- Lewis Wallenmeyer, Clark County
- John Willoughby, U.S. Bureau of Land Management

Thus, the expertise brought to bear on the issues regarding the efficacy of the 1994 Recovery Plan represented the highest level of scientific expertise available. It is important to note that this summary is intended to serve as a "strategic" review of the current Plan. We have conducted several new analyses of existing data to understand current status better or to illustrate various points, this report primarily provides recommendations for consideration in revising and more effectively implementing the Plan.

1.3 Overview of Observations from the Assessment

What follows in this report are evaluations of the original recovery plan in light of contemporary knowledge. Immediately below, we make eight general observations that bear on difficulties of implementing the original recovery plan or of lack of attempt to implement the original recovery plan. The remainder of the report is a more detailed summary of conclusions from this committee.

1.3.1 The desert tortoise invokes two fundamental challenges in understanding its biology and managing its recovery: time scale and detectability.

Time Scale – Desert tortoise recovery is fundamentally a demographic problem. Diminished populations require some period of population growth (average lambda > 1.0) to recover. Populations that are stable and secure may fluctuate in size in response to local, prevailing conditions, meaning that population growth rate (lambda) will vary around an overall stable mean (lambda = 1.0). However, desert tortoise natural history is not well suited to demographic analysis using short-term study by humans. Individual tortoises grow slowly, take many years to reach sexual maturity, and have low reproductive rates during a long period of reproductive potential. This means that studies of 1-10 years, or even longer, do not necessarily yield data of sufficient statistical power to reveal population trends.

Detectability – Desert tortoise behavior and morphology make tortoises very difficult for humans to detect and observe. The personnel and resources necessary to overcome the problem of low detectability have not been appropriate to allow precise estimates of population size of desert tortoise anywhere in the range of the species.

1.3.2 Desert tortoise faces simultaneous, multiple threats. Tortoises face an array of threats and these threats act simultaneously. This concept is central to recovery, because it portends profound difficulties in formulating effective recovery actions. In particular, a management action that alleviates one threat may not yield meaningful recovery because the deleterious effects another threat operating simultaneously suppress the gains sought by the original management action. In other words, one threat can negatively compensate for another threat when threats are simultaneous.

1.3.3 Threats to desert tortoises are interactive and synergistic. The magnitude of the deleterious effects of one threat can be a function of another threat. For example, if increased mortality reduces the lifetime fecundity of a female tortoise by removing that female from the population before she reaches her period of maximum annual fecundity, then deleterious factors to other life stages (e.g., raven depredation neonatal tortoises) may have a greater effect on tortoise demography. Why, because the negative effect on neonates is to a larger proportion those neonates in the population because new neonates are not produced when adults are killed. Also, disease may only be an important contributor to population declines during years of drought or to populations stressed by invasion of exotic plants or by off-road vehicles or any number of other stresses. In other words, threats to tortoise populations are complex because the threats interact to cause impacts rather than creating impacts just directly.

1.3.4 Recommendations made in the original recovery plan for carefully controlled experiments to generate data and analyses important to monitoring and recovery were not carried out. The original recovery plan recommended a suite of experimental approaches which, if carried out, could have provided key data and analyses needed for understanding tortoise population dynamics important in guiding current recovery. These recommendations appear to have been largely ignored. Ten years of opportunity to collect critical data and perform critical analyses have been diminished or lost for a variety of reasons. Unfortunately, the current recovery effort will pay the price for this missed opportunity. This grave mistake should not be repeated!

1.3.5 Much of the data currently available to address tortoise recovery was originally collected for purposes other than addressing tortoise recovery (hence we are doing meta-analyses using data of mixed quality to perform analyses be more efficacious using data from well designed studies). Perhaps for historical reasons, certain tortoise studies have been carried out more-or-less continuously. For example, permanent study plots have been maintained and contained tortoises studied. Various forms of distance sampling have been carried out at mixed levels of magnitude and intensity. A more efficient approach for the future might be to design studies using statistical and scientific expertise expressly to obtain key data to address central problems.

1.3.6 Mapping of even poorly collected data reveals very important apparent patterns. Technological advances since the first recovery plan have resulted in powerful analytical tools that bear directly on analyzing and monitoring desert tortoise populations. In particular, GIS analyses of data diligently derived from large, disparate data sets that were collected by various agencies are yielding intriguing patterns. “Mining” historical data and applying powerful new analyses or applying older analyses in new ways will be helpful in prescribing recovery actions. As demonstration of the substantial value of this approach, we present several new analyses including from existing data. These include (i) a kernel analysis of spatial distribution of live and dead tortoises, (ii) a cluster analysis of spatial distribution of live and dead tortoises, (iii) a spatial analysis of the probability of finding live versus dead tortoises, (iv) a multi-dimensional, multi-scale approach to monitoring, (v) a threats network topology, (vi) a quantitative literature review of all available tortoise literature, (vii) a weighted ANOVA of tortoise density from permanent study plots across 24 years, and (ix) a spatial analysis of the implementation of recovery actions from the first recovery plan.

1.3.7 No group is charged with managing scientific data on the desert tortoise. Currently, important desert tortoise data are widely scattered among state and federal agencies and the scientific community. Data have been gathered, organized, and stored in a multitude of ways. Some data have been reviewed, collated, or otherwise organized. Other data have not. Accessibility of tortoise data to managers, scientists, and the public is highly variable. In short, a great deal of important long-term data cannot be readily used. This is an ineffective data management strategy for species recovery. A new infrastructure for ensuring quality, accessibility, and analyses of data is desperately needed.

1.3.8 Scientific Information important for recovery is entirely ad hoc. There is no oversight or advisement on the expenditures of scientific resources directed toward gaining new knowledge on desert tortoise or Mojave ecosystems. In spite of the fact that the desert tortoise recovery plan mapped out an initial research agenda for desert tortoise and Mojave ecosystems, scientific resources have been expended with little regard for that agenda. Thus, the limited supply of tortoise biologists are frequently absorbed into contracts for local issues (e.g., DOD needs for data to comply with NEPA). Some HCPs have scientific oversight and direction, but there is essentially no coordination of the scientific enterprise conducted in different management units in a way to get more than accidental accumulation of necessary accumulation of knowledge important for managing the desert tortoise and its ecosystems.

2. Quantitative Literature Review: the state of knowledge

The most recent annotated bibliography published on desert tortoises (*Gopherus agassizii*) identified trends in research prior to 1991 and mentioned gaps in knowledge, which influenced research prescriptions in the Desert Tortoise Recovery Plan (1994) (Grover and DeFalco 1995). The original Recovery Team made several recommendations for research necessary to fill information gaps important to the recovery of desert tortoise populations. These items included:

- long-term demography (particularly recruitment and survivorship of younger age classes, sources of mortality, and epidemiology),
- population structure (spatial scale of genetics and demography)
- long-term analysis of impacts,
- effectiveness of protective measures,
- spatial variation in climate and vegetation,
- nutritional and physiological ecology, and
- reproductive behavior and physiology

The recovery plan highlighted the need for long-term studies, which are necessary to capture temporal variation and ecologically relevant trends. In addition, the recovery plan prescribed research on non-reproductive age classes, which are rarely studied and underrepresented in the literature. Few studies have been conducted on survivorship, recruitment rates, and mortality in young *Gopherus* tortoises, resulting from their cryptic morphology and behavior.

A recent literature review employed a quantitative approach to 1) compare the foci of research before and after the publication of the Desert Tortoise Recovery Plan, and 2) identify present gaps in desert tortoise knowledge (Hagerty, Sandmeier, and Tracy in preparation). All obtainable desert tortoise literature provided by the Clark County Multi-Species Habitat Conservation Plan database (1378 total) were classified by age class, literature type, and one or more research categories (Table 2.1). Contingency table analyses were performed to determine differences among the types of research before and after the recovery plan was published.

TABLE 2.1. Research categories used in quantitative literature review.

Research Category	Relevant topics included in each category
Ecology	life history characteristics, demography, and ecology
Autecology	physiology, behavior, and morphology
Conservation	threats, management, and effectiveness of conservation efforts
Systematics	molecular and morphological systematics
Disease	pathology, veterinary procedures, pharmacology
History	natural history, evolution, fossil record, paleoecology
Bibliographies	literature reviews and annotated bibliographies

Academic researchers and agency biologists communicate their results in professional journal, government documents, Desert Tortoise Council (DTC) symposia, and other professional society meetings. Overall, 22% of available desert tortoise literature was published in professional journals. After the recovery plan, the amount of literature published in professional journals increased, while the percentage of gray literature decreased (Fig. 2.1). The latter result may be an artifact of the availability of government reports, however there is a definitive trend for researchers to publish their results in professional journals.

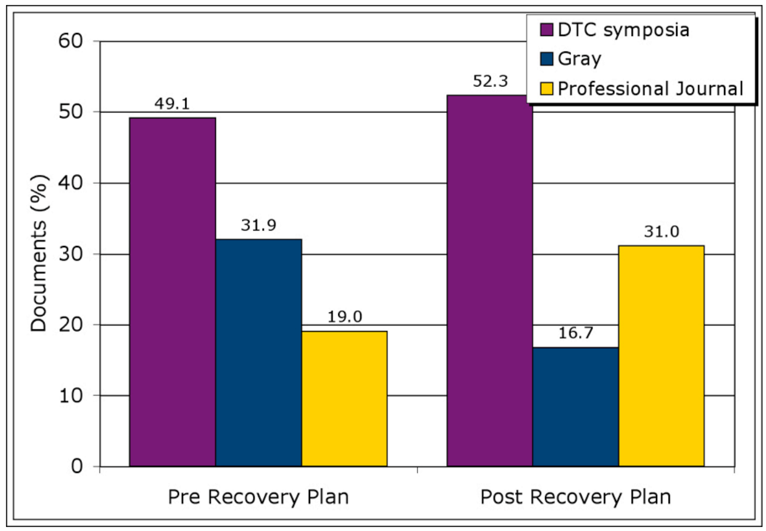


Fig. 2.1 Distribution of all literature types before and after the publication of the recovery plan.

Further, professional journal documents were dominated by autecology research, while other documents contained mainly conservation and ecology studies ($\chi^2 = 154.115$, df = 6, $p<0.0001$) (Fig. 2.2). This result may suggest a dichotomy of research being done within agencies and academia, respectively. Tortoise conservation studies consist mainly of descriptions of threats to tortoises and how these threats are being managed. Population density and habitat studies, which are typically performed by government agencies, are also included in the gray literature category.

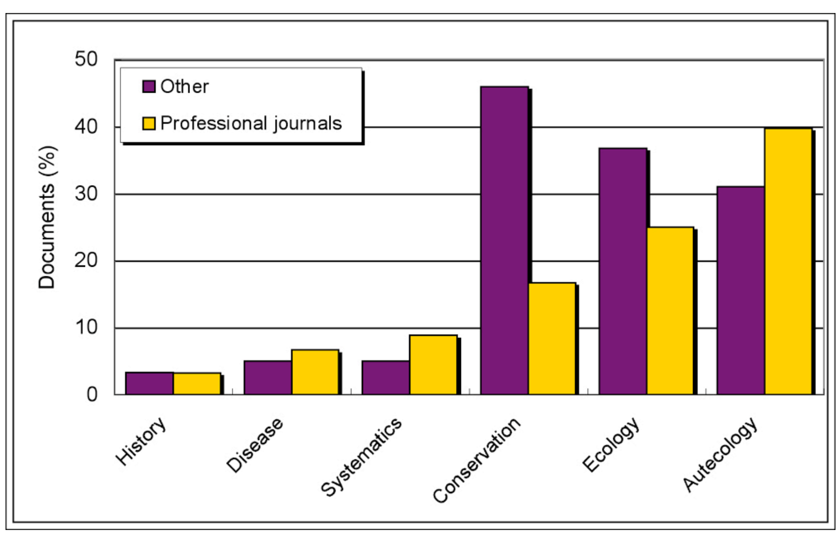


Fig. 2.2. Distribution of literature among the major research categories.

The recovery plan prescriptions for future research did appear to have a limited impact on desert tortoise research. After the recovery plan, more documents in professional journals focused on ecology and conservation implementation, with a continued emphasis on autecology ($\chi^2 = 25.88$, df = 5, $p<0.0001$) (Fig. 2.3). A change in the distribution of gray literature also corresponding to the publication of the recovery plan was marginally statistically significant ($\chi^2 = 13.49$, df = 7, $p<0.06$).

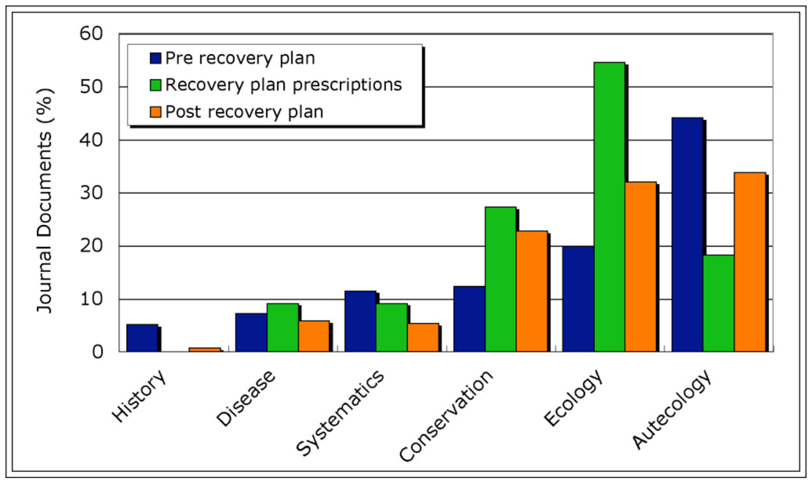


Fig. 2.3. Distribution of professional journal literature in the research categories before and after the publication of the recovery plan.

Since the Recovery Plan was published, there has been considerable research on some aspects of tortoise biology, in particular nutritional ecology, reproductive physiology, and the effects of several impacts on tortoise populations. However, very little research has been published on other important topics recommended, such as long-term demography, effectiveness of recovery actions, and climatic and vegetative variability. On other topics, such as epidemiology and many long-term impacts on tortoise populations, virtually no research has been conducted or published. Some additional areas of active research, not identified in the Recovery Plan, include disease and health status, habitat conditions, and fire ecology. In the case of disease, recent studies focused on pathology instead of epidemiology, which was prescribed by the recovery plan. These new areas of research are important and should be continued, however not at the cost of not implementing recovery team recommendations.

Research prescriptions in the recovery plan (1994) also emphasized the need for research on immature age classes within the categories of ecology and autecology. In particular, the recovery plan recommended research on recruitment and survival rates of non-reproductive age classes and their nutritional and physiological ecology. After the recovery plan, an increase in the percentage of studies on immature age classes corresponded to general prescriptions in these areas, suggesting that the recovery plan prescriptions were effective (Fig. 2.4). However, no studies were done specifically on recruitment and survival of young age classes. A quantifiable deficiency in knowledge of non-reproductive tortoises remains a missing link to understanding desert tortoise population structure and dynamics. Literature on early life stages is under represented in all age-relevant categories, with only 5% of documents focusing exclusively on immature life stages.

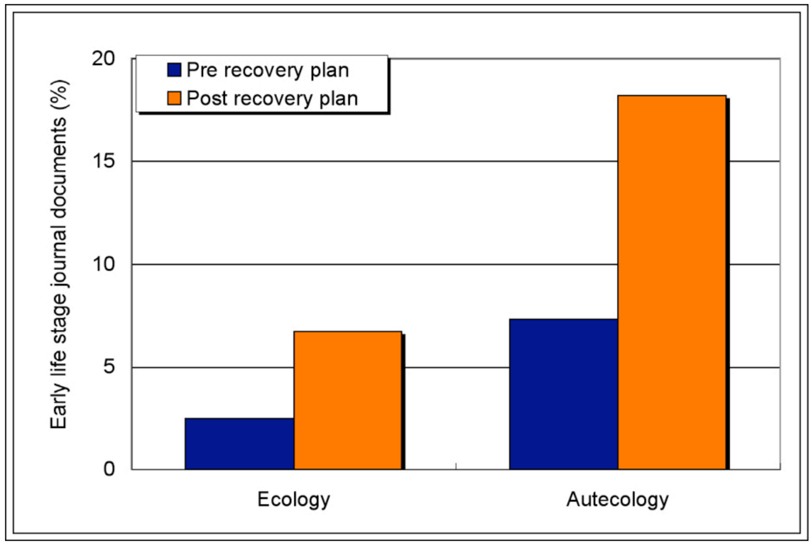


Fig. 2.4. Percent of early life stage documents in professional journals that focused on ecology and autecology.

Implementation of effective management strategies to recover the Mojave population of *Gopherus agassizii* requires an accurate characterization of population structure, threats to population persistence, and the effectiveness of protective measures. Determining life history characteristics, such as age-specific survivorship, is critical and requires large sample sizes and long study periods. In addition, hypothesis-based experiments on the long-term effects of recovery actions are also necessary. These gaps in knowledge were identified in the recovery plan, have not been addressed, and remain important prescriptions for research.

3. Distinct Population Segments (DPS)

3.1 Definitions and intentions of Distinct Population Segments

3.1.1 Definition –

The Department of the Interior (DOI), 1996, designated DPS based upon three elements for recognizing individual sub-populations of a single species for differential protection under the Endangered Species Act (ESA).

(1) **discreteness** of the population segment in relation to the remainder of the species to which it belongs

(2) **significance** of the DPS relative to the species to which it belongs

(3) **conservation status** of the population in relation to the ESA standard for listing.

This stands as the current legal definition for DPS, but it requires some explanatory qualifications to facilitate implementation. In addition, an historical context will be provided under "*The Problems*" section that follows. Imbedded within the current definition are several qualifications so compelling that they should be addressed as functional adjuncts to the definition itself. First, the criterion of discreteness must be satisfied as prerequisite to recognizing both the physical existence (= geographical reality) and the biological/conservation significance (criteria #2 and 3) of a proposed DPS. Congressional statutes make clear that the purpose of recognizing such units as discrete is to preserve genetic diversity.

DPS and Evolutionarily Significant Units were until 1994 largely equated with one another, and under some DOI polices in the NMFS are treated as synonyms. While these terms have grown apart in comparative biology, they have a common original purpose, namely delineate genetically distinct subpopulations with the potential for individual evolutionary trajectories. In some sense, these units replace the poorly defined and highly subjective anachronism of subspecies (Frost and Hillis, 1990; Frost et al., 1992). Influenced in part, by the traditional use of morphology, and more recently genetics, in defining subspecies, the DOI cites the use of these lines of evidence as appropriate parameters by which to define DPS. However, these criteria were not to exclude other important information.

Statutory wording also cautions that differential protection of DPS be applied "sparingly" to units which have both the potential for persistence, and which are differentiated in features that have evolutionary and/or conservation significance. While genetics is generally recognized as the primary determinant of evolutionary distinction, the definition and precedent use of DPS for the ESA allows both genetic and evolutionary significance to be inferred from other parameters. Even compelling differences in conservation status among subdivisions of a species may be invoked both to define and justify a DPS (e.g., health status, differential conservation across international boundaries).

3.1.2 Problems and their Potential Resolution

Difficulties in the application of the term DPS largely hinge on the questions listed below.

(1) What degree of genetic/evolutionary distinctness, either demonstrated or inferred, justifies a DPS designation for a specific spatial entity as “discrete”?

(2) What degree of ecological or behavioral differentiation, conservation status, and/or internal homogeneity would make a DPS significant?

(3) What constitutes distinct conservation status and significance?

(4) To what extent do our existing databases for the desert tortoise subpopulations north and west of the Colorado River make it possible to discern distinctness and document both ecological significance and conservation status?

Each of these questions has subordinate problems/issues imbedded in them.

3.1.3 Distinctness

Resolution of the issue of distinctness is the most compelling justification of a new DPS. Determining distinctness is intrinsically challenging because it involves diverse criteria, subjective judgments about degrees of distinctness, and a perspective from comparative biology that places “discreteness” or distinctness in context of its particular taxonomic unit. The difficulty of determining distinctness has been exacerbated by the historical commingling of terms like DPS, ESU, and Recovery Unit as in the 1994 Desert Tortoise Recovery Plan (Pennock and Dimmick, 1997; Berry et al., 2002). Furthermore only core areas of most DPS are resolved by current databases. Discrete borders of DPSs may not be so easily obtained from currently available databases (see Mcluckie et al, 1999 for illustration of the complexity of even using the Colorado River as boundary).

At the time The Desert Tortoise Recovery Plan (1994) was written, Distinct Population Segments (DPS) were equated with Evolutionarily Significant Units (ESU) (Waples, 1991). The definitions of ESU and DPS were both employed in defining “recovery units” in the Plan. However, the term “recovery unit” appears to be eclectic and unique to the 1994 Desert Tortoise Recovery Plan. DPS designations within the Mojave Population need to conform to the modern definition (Berry et al., 2002), and should replace past references to both ESU and recovery units. Since the Plan was written, definitions of DPS and ESU have diverged. Since 1994, ESU has become much more narrowly defined in the discipline of comparative biology, where it is most often used. Typically, ESU refers to conspecific populations that are distinguishable by substantial and mutually monophyletic differences in their mitochrondrial or nuclear DNA sequences (Moritz (1994, 2002, see also its use by Avise 2000), differences sufficient to reflect past geographical isolation by “vicariance events (Berry et al. 2002). Currently only the National Marine Fisheries Services still utilizes a narrow, genetic definition to designate DPS status, most prominently for salmonid fish (Pennock and Dimmick, 1997) and fresh water mussels (Nammack, 1998). For most taxa, the DOI applies the much broader definition of DPS, provided above, for reasons reviewed by Pennock and Dimmick (1997). In terms of legal policy, agency and court precedence, and practicality, it is the broader definition of DPS that is particularly appropriate for defining subdivisions of the desert tortoise (Berry et al., 2002). Regardless of the historical divergence of ESU from the broader DPS, these concepts share a common objective of conserving genetic diversity and divergent evolutionary trajectories, whether these trajectories are demonstrated specifically through DNA (ESU *sensu stricto*) or inferred through both direct and indirect evidence (DPS *sensu lato*).

The distinction between distinctness and significance comes directly from the criteria for recognizing a DPS. A DPS can be recognized only if it is a "distinct" and "significant" subdivision of a species. The criteria for recognizing a DPS originated from the criteria used by the NMFS for recognizing an ESU (Nammack 1998) even though the two terms have since diverged in the scope and application.

Distinctness traditionally has referred to reproductive isolation from other conspecific population units (Nammack 1998). Yet, by definition, DPS units are conspecific, so the reproductive isolation is less than complete reproductive incompatibility. Reproductive isolation may be based on geographical, ecological, physiological, or behavioral difference(s), and quantitative genetics or morphology may be used as evidence of such difference(s). Although quantitative genetics has an arbiter to assist distinctness (e.g., Spidle et al. 2003), other evidence of reproductive isolation may be considered (e.g., Haig et al. 2002), especially in the context of current DOI definition of DPS. In the case of the desert tortoise, quantitative biochemical/genetic information is available (Rainboth et al.1989, Britten et al., 1997, Lamb and Lydeard, 1994, and McLuckie et al., 1999), and it should be used as the primary database.

A second obvious source of comparative data is morphology. Morphological/meristic differences are traditional tools of taxonomists. Indeed, virtually all chelonian species and subspecies have been defined, almost exclusively in terms of morphology. Such evidence may be misleading, especially at the subspecies level, particularly given the susceptibility of tortoise shell ontogeny to environmental factors (e.g., diet, seasonality, temperature regimes, etc., see Berry et al., 2002 and Jackson et al., 1976) that are not heritable. If, however, reproductive isolation is not detected, because of incompleteness of genetic or morphological sampling, recentness of the isolating mechanism, anthropogenic translocations of individuals, or other reasons, then a case may be made for (1) additional quantitative genetic sampling in specific locations and/or (2) recognition of a DPS based on other criteria. However, such designations would be extremely difficult justify, because they would require extensive knowledge of organism-environment interactions (actually it might well require more knowledge than we are able to obtain within the foreseeable future).

The more generous definition in current use by USFWS (Pennock and Dimmick, 1997) convey "distinction" to DPS units using criteria that would not justify distinction in a literal evolutionary sense, but are very relevant both to the conservation of species like the desert tortoise in particular. Examples including recognizing populations fragmented/isolated by international boundaries and those subject to different threats/management policies, populations which are positioned to fill distributional gaps and maintain critical gene flow, and populations that differ from one another in health status and consequent conservation management needs. Behavioral and ecological differences among populations may be used both to infer genetic/reproductive isolation and to establish the ecological significance of a proposed DPS, but the two concepts are so intertwined that they will be discussed together in the following section.

In most cases, only DPS core areas may be defined but their boundaries are rarely discerned. Both spatially inadequate, and genetically incomplete, sampling precludes the resolution of such boundaries. This task needs to be addressed for many reasons, but especially when new DPS units are being subdivided from old, or when a pre-existing unit is subsumed into another.

3.1.4 Ecological/Behavioral Distinction & Significance

Ecological and behavioral criteria need to be considered under the current definition of DPS. Genetic evidence generally comes from small samples of the genome of the species, and phenotypic differences in ecology and behavior also can provide evidence of genetic distinctness. Additionally, ecological differences establish the "significance" of differences among populations. This, if a sub-population already has been demonstrated to be genetically "distinct," when should it be considered ecologically "significant"? The criteria for determining significance are better understood in the context of specific criteria or examples. DOI provides specific examples of conditions that gauge the "significance of a DPS". These include:

(a) persistence in a unique or unusual setting

(b) geographical distribution that would otherwise leave a gap in the species range

(c) only surviving population within historical distribution

(d) marked differences in genetics of individual populations

A "significant" subdivision refers to evolutionary legacy. Thus, a DPS should either represent an independent component in the evolution of the species (Nammack 1998) or an irreplaceable component in the conservation of the species in its full diversity (Pennock and Dimmick, 1997).

What would be convincing ecological evidence that a DPS represents an independent evolutionary component or irreplaceable component in the conservation of a species? We propose that adequate evidence is a difference in life history trait(s) such that individuals in the putative DPS may be affected differently from individuals elsewhere when faced with the same threat(s) to population persistence. Unfortunately, this criterion is not independent of existing threat(s) because data on pre-threat(s) are lacking. Thus, a more tractable criterion might be difference(s) in life history trait(s) such that individuals in the putative DPS may be affected differently from individuals elsewhere when faced with new threat(s).

Life history traits are adaptations influencing survivorship and reproduction. These adaptations include age and size at reproductive maturity, length of reproductive life, clutch size and size of hatchlings, number of clutches per year, sex ratios, mating systems and sperm storage, etc. Differences in these traits are the result of selection in different environments. Thus, life-history theory predicts that when stochastic selective pressures differentially select against young tortoises, then there should be life-history adaptations to increase the length of reproductive life of adults. Alternatively, when stochastic selective pressures differentially select against adult tortoises, then there should life-history adaptations to produce larger clutches of eggs. Thus, when there are differences in life histories among populations, and when there are threats to a sensitive species, then the adaptations to environments can be inadequately matched to environments. Thus, the life-history traits most likely to contribute to the evolutionary independence of a sub-population are those that reflect the adaptation to place and contribute to ecological success.

Sometimes an understanding of these important life-history traits can be captured with a small number of population-level attributes. For example, age-specific mortality rates, clutch size and number of clutches each year, bodily growth rate, body size at reproductive maturity, primary and secondary sex ratios (e.g., Tanner 1978). More recently, ecologists have been able to infer much of importance in ecological attributes contributing to the evolutionary independence of a sub-population from genetics, dispersion and dispersal, and size and arrangement of habitat patches (see Krebs 1994, Ricklefs and Miller 1999). A fundamental list of population-level attributes for monitoring species recovery would be very similar, and include population size, demographic rates, mode of reproduction, and age at sexual maturity (e.g., Hoekstra et al. 2002).

Even though the information needed to understand the basic ecology of a species is reasonably clear, lack of knowledge about the basic biology of rare species often plagues recovery plans (Tear et al. 1993, Schemske et al. 1994, Crouse et al. 2002). While such information is largely lacking or inadequate to characterize existing DPS units within the threatened Mojave tortoise population, a robust set of life-history characteristics, both stable and pronounced in their differences, distinguish the Mojave desert tortoise from its counterpart in the Sonoran desert. The degree of isolation between populations east and west of the Colorado River correlates well with parallel genetic data used to separate the two currently conspecific groups of populations (Van Devender, 2002). For this reason, we do not entirely discount the eventual discovery of similar, if less pronounced, life history differences within Mojave tortoise populations.

With the list of important population-level attributes in hand, we are in a position to develop a hierarchy of ecological evidence that can be used to determine if a putative DPS actually represents an independent evolutionary component. A suggested list follows, arranged from the most- to the least-convincing evidence.

3.1.4.1 Direct Life-History Measures:

(a) survivorship
(b) fecundity (clutch size and frequency)

(c) dispersion rates
(d) seasonality of mating and hormonal cycles
(e) size at reproductive maturity
(f) bodily growth rate, and sex ratio

3.1.4.2 Ecological/Demographic Indicators:

(a) age distribution / size distribution
(b) population growth rate
(c) sex ratio/mating system
(d) age at sexual maturity/generation time
(e) reproductive value (per age class)
(d) body size / number of clutches/timing of reproduction
(e) population density

3.1.4.3 Possible Environmental Correlates:

(a) vegetation – both for diet /shelter
(b) rainfall
(c) soils
(d) burrow size, shape and orientation; hibernacula
(e) other habitat variables (slope, proximity to ephemeral water channels, etc.)

3.1.5 Deficiencies and Limitations of Existing Databases

At least three caveats accompany this list. (a) Short- and long-term variability in any of these measures, indicators, or correlates could be important in concert with each other or independently. (2) It is not likely that direct demographic measures will be available from throughout a putative DPS, so establishing boundaries may require use of indicators and correlates, once their relationships to direct demographic measures have been established. Likewise, the establishment of long-term (10-20 year) study sites could verify correlates (the could even serve to "ground truth" remote sensing inferences). (3) Significant differences in any of these measures, indicators, or correlates between two locations can be established with standard statistical techniques.

3.1.6 Significance to Conservation

The emphasis on threat(s) is further re-enforced by recent evaluations of recovery plans. These evaluations have led to several recommendations for improving the use of science in recovery plans (Clark et al. 2002). These recommendations include: (1) make threats a primary focus, (2) specify monitoring tasks for species status and recovery tasks, (3) ensure that species status-trend data are current, quantitative, and documented.

Significance to the conservation of the species adds another set of relative and comparative criteria by which to identify a subpopulation as distinct and to justify its legal protection as a discrete entity. Particularly germane to the Desert Tortoise populations, so many of which are differentially affected by Upper Respiratory Tract

Disease and other health threats, is the fact that health status should be used to recognize an individual population as distinct and significant (Pennock and Dimmick, 1997).

3.1.7 DPSs of the 1994 Desert Tortoise Recovery Plan

The current Recovery Units represent appropriate hypotheses of distinctiveness. Certainly all of the Desert Wildlife Management Areas within these recovery units are valuable to the conservation of the desert tortoise. However, each of the following Recovery Units must be reviewed under the more current and elaborate definition of DPS provided above.

1 - Northern Colorado	2 - Eastern Colorado
3 - Upper Virgin River	4 - Eastern Mojave
5 - Northeastern Mojave	6 - Western Mojave

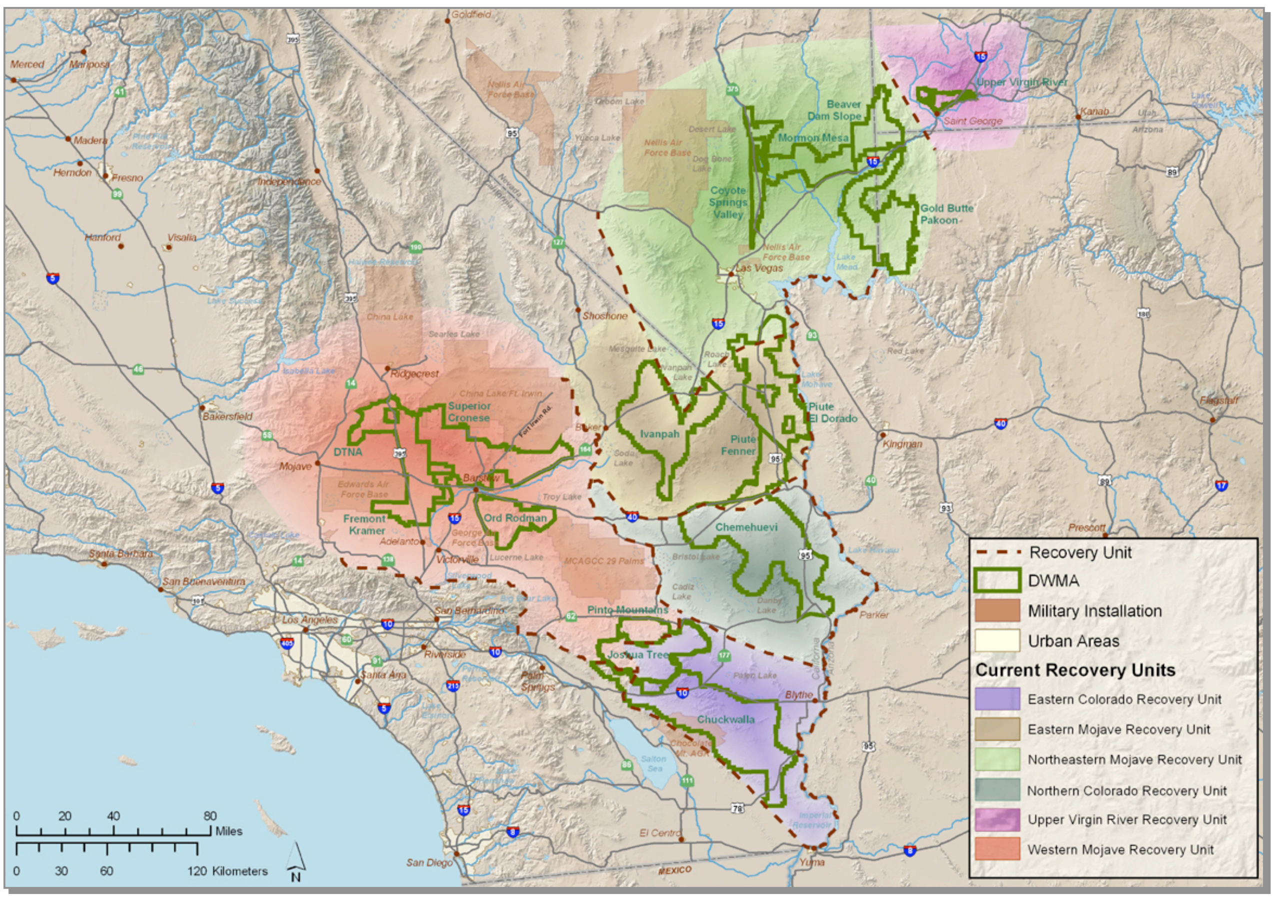


Fig. 3.1. Depiction of recovery units proposed in the 1994 recovery plan. Green outlines within the recovery units are proposed DWMAs.

The question now becomes how well justified are these units in terms of modern use of the DPS. Should some be split, merged or eliminated?

3.2 Reappraisal of current DPS units

The desert tortoise exhibits extensive genetic (Lamb et al. 1999, Lamb and Lydehard 1994), morphological (Weinstein and Berry 1987, Germano 1993), physiological (Turner et al. 1986, Wallis et al. 1999, Averill-Murray et al. 2002a, Averill-Murray 2002c), and behavioral (Woodbury and Hardy 1948, Burge 1977, Averill-Murray 2002b) variation throughout the species range (Berry et al. 2002). Initial genetic studies categorized three assemblages of *Gopherus agassizii* with distinct geographic distributions (Jennings 1985, Lamb et al. 1989, Glenn et al. 1990). These major genetic assemblages were resolved with a parsimony approach, using relative mitochondrial DNA differences exhibited by the other North American tortoise species (Lamb et al. 1989). Recognizably different shell morphology between populations east and west of the Colorado River corresponds to the two described assemblages north of Mexico (Weinstein and Berry 1987). Habitat diversity among assemblages provides additional evidence for their consideration as discrete units (Berry et al. 2002). There is overwhelming support from several facets of science, which point to a clear separation between the Mojave and Sonoran assemblages of the desert tortoise. Further genetic differentiation in the Mojave assemblage has been acknowledged in the Desert Tortoise Recovery Plan (USFWS 1994).

Of the six original DPSs, three appear to be well justified as distinct from other units by multiple criteria. In order of decreasing significance, the Upper Virgin River, Western Mojave, and Eastern Colorado. Ironically, the best-defined DPS, the Upper Virgin River, is perhaps the least capable of population persistence without extensive management due to its small geographic size. The remaining three DPSs need to reevaluated, possibly redefined, and their Desert Wildlife Management Areas (DWMA) may in some cases need to be reassigned. The Eastern Mojave and Northern Colorado units have particularly poor justification as separate DPSs from each other, despite the geographical importance of their DWMAs. The Northeastern Mojave unit might be both refined and subdivided based on the post-Plan study of Britten et al. (1997), as further noted below. Under the descriptions of “Recovery Units” provided by the 1994 Recovery Plan (p.20-22), many of these putative DPS units are described as supporting tortoise populations living in a wide range of ecological settings within one unit. This may appear to be antithetical to the establishment of ecological significance where the emphasis is upon the uniqueness and homogeneity of ecological affinities of the tortoise population within that specific DPS unit, but it does not immediately follow that a wide range of ecological settings in each unit would necessarily obviate uniqueness.

3.2.1 Options for Revision

The existing DPS represent three categories.

3.2.1.1 Not ambiguous DPS relative to genetics,
e.g., the Upper Virgin River

3.2.1.2 In need of revision,
e.g., the Northeastern Mojave unit appears to need further subdivision based upon genetics alone.

3.2.1.3 Poorly Justified based upon DNA evidence alone,
e.g., contemporary evidence suggest a close affinity between the Eastern Mojave and Northern Colorado units .

Currently, the Eastern Mojave Unit combines distinctive California and Nevada haplotypes. Depending on further elucidation of geographical boundaries of discrete genetic lineages, the current Eastern Mojave DWMA conceivably could be assigned to the Western Mojave DPS, or to a new Piute Valley DPS, or a revised Northeast Mojave DPS. Many of these revisions will require more data and analyses as well as evaluation and expansion of the analyses of Britten et al. (1997).

The entire complex east of the Baker Sink needs a more data and analyses as well as comprehensive reevaluation in terms of genetic diversity and ecological geographic boundaries. An attractive division line within the Western Mojave DPS runs along a line from Saline Valley in California in the north south through Death Valley, Silurian Valley, Baker Sink, and Cadiz Valley in the south. It is particularly attractive because the lower elevations and extremely hot climates along this line divides the ecological western Mojave Desert with its quite variable winter-spring precipitation regime, lower elevations, and Mojave River hydrology, from the more eastern Mojave Desert, subject to with more predictable winter and summer monsoon precipitation, more variable elevations, and closed basin and Colorado River hydrology. Rainfall pattern differences (Fig. 3.2) induce profound vegetation differences, forage and possibly reproductive differences (seasonality of mating, egg clutch size, frequency and timing). Furthermore, rainfall differences create the potential for different interactions among threats (See threats section).

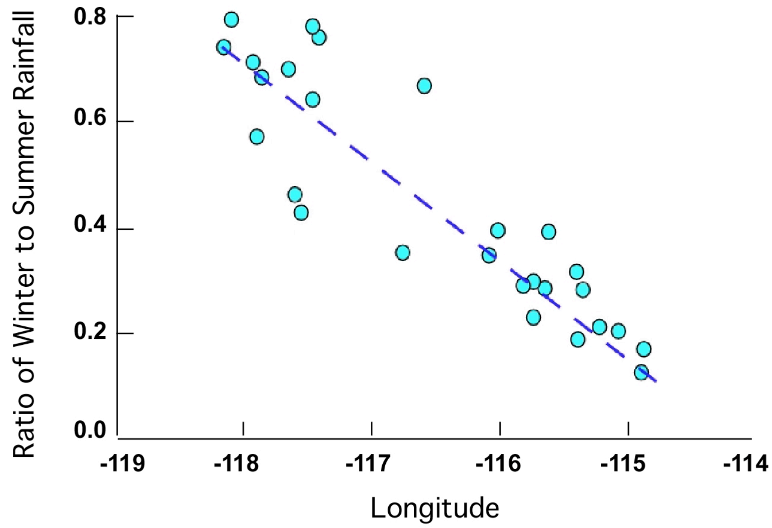


Fig. 3.2. Ratio of rainfall in winter compared to summer. in the Mojave Desert.

While life history patterns and strategies should be expected to differ in tortoise populations east and west of the Baker sink, they have not yet been demonstrated. Tortoises are rare in the lowlands comprising this division, yet they are not entirely absent. Furthermore, neither allozyme nor mitochondrial comparisons yet support differentiation across this axis of potential separation (Rainboth et al., 1989; Lamb and Lydeard, 1994).

Prior genetic studies pertinent to the foregoing case and others are largely piecemeal, confined to mtDNA or limited allozyme or morphological data. They provide us with little insight with regards to gene flow or discrete boundaries. Furthermore, future genetic studies would be most efficacious, if they included the entire clade of *G. agassizii* and *G. berlandieri*. This should be a component of the second provision of the DPS definition. Depending on the outcome of these studies, “Eastern Mojave” populations could be assigned to anywhere from one to four DPSs. The discussion above is provisional and based upon insufficient data for a final resolution. In making these critical remarks, we note that virtually all of the critical habitat units are well justified to sustain survival of *G. agassizii*. It is only their assignment to particular DPSs that concerns us.

With regard to revision of the Northeastern Mojave DPS - the Mormon Mesa and Coyote Springs DWMAs might be assigned to a Lower Virgin River unit. This might also include Beaver Dam Slope and Gold Butte Pakoon DWMAs. In contrast, the Piute-Eldorado DWMA might be assigned to a separate DPS. A new Northeastern DPS could include less than does the current Northeastern recovery unit.

The two and one half page (pp. 20–22 of the Plan) justification and characterization for recognized DPSs needs to be expanded and standardized. The same criteria should be noted for all DPSs.

We offer here a provisional recognition of a new set of DPS units. These include two the original units (Upper Virgin River and Western Mojave) and add or revise four other units, based largely on the best resolving biochemical/genetic data of Rainboth et al., 1989, Lamb and Lydeard (1994), and especially Britten et al, (1997). Using an entirely genetic database to establish primary "distinction" is our primary task. However, it is also merely a first cut. We do not consider these divisions definitive. In the last section of this report, we will establish broad criteria and protocols for their further revision, division, or deletion.

3.2.2 Recommendations for a Provisional Revised List of DPS units (Fig. 3.3)

Upper Virgin River Desert (including Beaver Dam Slope) - USFWS 1994
Lower Virgin River Desert - Britten et al., 1997
Northeastern Mojave Desert (including Amargosa Valley, Ivanpah Valley, and Shadow Valley) - Britten et al., 1997
East Mojave and Colorado Desert - Britten et al., 1997
Western Mojave Desert - USFWS, 1994-

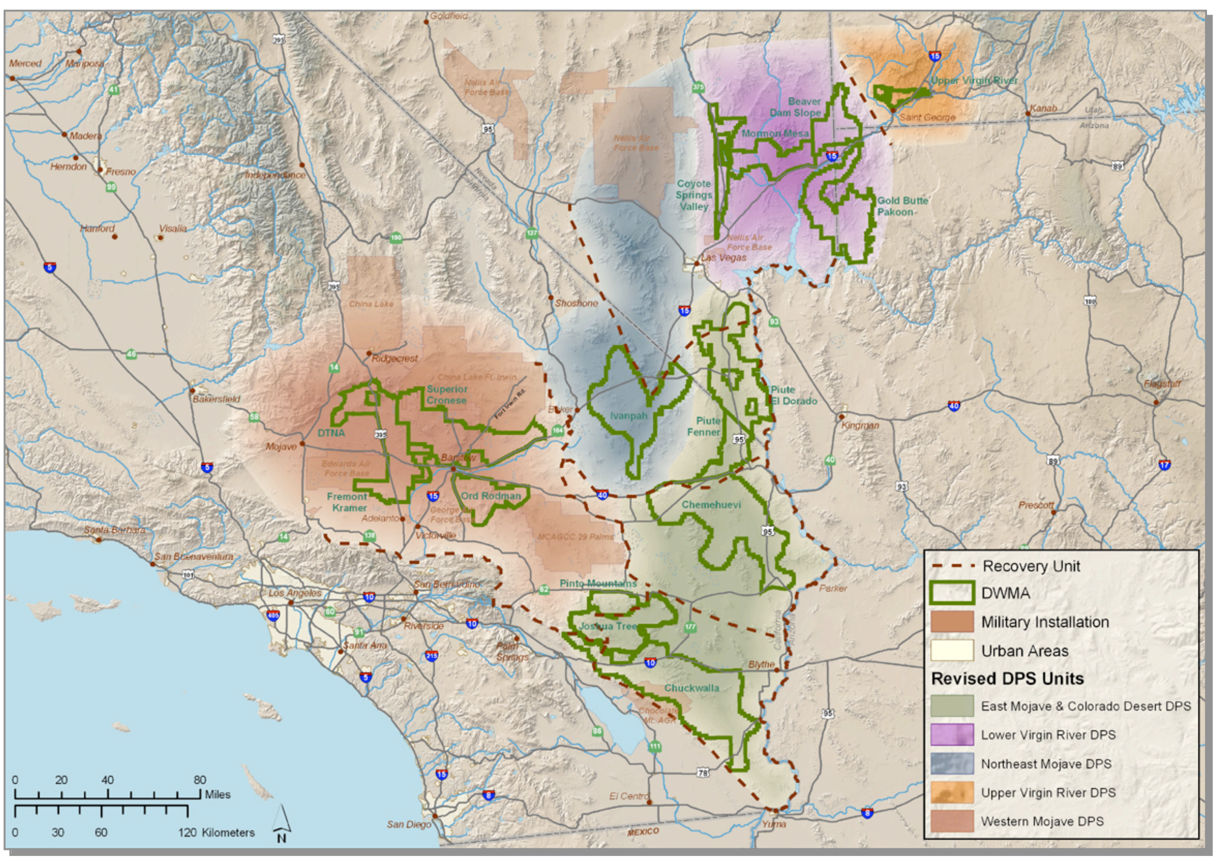


Fig. 3.3 – Map of the proposed distinct population segments for desert tortoise.

3.2.3 Recommendations for Future Reassessment of DPS

Future revisions will need to respond to the three criteria by which modern DPS units are defined: discreteness, significance, and conservation status. The mechanisms are as follows:

- Genetic core units need to be assessed using both nuclear and mitochondrial genes (Berry et al., 2002).

- The genetic boundaries and gene flow among units needs to be critically examined.

- Once these data are available, ecological, morphological and behavioral attributes should be assigned to each of these genetic units. Correlations among established genetic units and carefully quantified and standardized ecological affinities, health status, life history patterns, and stereotypic behaviors.

- The natural history of host-parasite associations for the major disease relationships for desert tortoise should be more deeply elucidated including the genetics of hosts and strains of pathogens.

- At least three disparate, long-term study sites should be established within each proposed DPS to verify the reality, consistency, homogeneity, and variability of these defining traits.

- Finally, DWMAs within each DPS should be geographically revised to maximize their conservation potential in consultation with ecologists and local resource administrators.

4. Status and Trends

4.1 Status and Trends of Tortoise Populations

4.1.1 Introduction and Background

No data or analyses are currently efficacious to estimate status or trends in desert tortoise populations, habitat of tortoise in recovery units, or threats to tortoise regionally. We have assembled the existing data to perform the equivalent of meta-analyses on existing information. Data on population densities have been assembled from numerous sources. These data all have inadequacies, but they can be used to estimate the status and trends of desert tortoise populations with certain provisos.

At the time of the writing of the 1994 recovery plan information regarding the status of desert tortoise populations was largely dependent on analyses of tortoise densities from permanent study plots. While these data showed that populations were experiencing significant declines in the western extent of the listed range (i.e. California, Recovery Plan Introduction section Page 4, Fig. 1), no trend in adult densities for the eastern portion was discernable at the time the recovery plan was written (Recovery Plan, Appendix C, Page C9, Figure C4). Interpretations of analyses of PSP data were controversial (Corn, 1994, Bury and Corn 1995), and new sampling methods were called for. Permanent study plots continued to be sampled in the years following the publication of the recovery plan, and many continue to be sampled today. However, many of the study plots in Nevada, and Utah were not sampled beyond ~ 1996, as new methods of density estimation were being developed and employed around that time. Thus, the current status of tortoise populations in California as measured by data taken from PSPs is more current than that from Nevada, or Utah. Nevertheless, data beyond that relied on by the recovery team in 1994 are available, and are analyzed herein, and those analyses show similar patterns in trends of tortoise densities to those published in the 1994 plan.

4.1.1.1 Long-Term Study Plots

Long-term study plots were established in California in the early 1970's as part of an inventory of Bureau of Land Management resources (Berry 1984). These plots were to generate data on demography and population trends as well as ecological relationships with abiotic and biotic factors in different plots (Berry 1984). Various methods were used to assess population size in the initial surveys on those plots (e.g., 30-day spring surveys, 20-day fall surveys, and winter den surveys), but eventually a standard method became the 60-day spring survey of a one square mile plot. Survey effort is divided into two periods of roughly equal times (capture and recapture periods). Tortoise density was estimated using the Lincoln-Peterson calculation (Turner and Berry 1984); analyses for most plots limit abundance estimation to tortoises $\geq$180 mm MCL, due to reduced capture probabilities for smaller tortoises, but abundance of tortoises of all sizes on California plots is often estimated with the stratified Lincoln Index (Overton 1971). Additional data collected on study plots include health profiles, burrow or cover characteristics, tortoise size, information on carcasses, and vegetation transect data. Few of these latter data have been analyzed beyond descriptive summaries. In general, the 60-day spring survey is the basic design from which most pre-distance sampling data on desert tortoise status and trends are based.

Plots were typically located on public lands and in areas containing "adequate tortoise densities for sampling," sometimes specifically where large numbers of tortoises had been reported; however, some plots were originally located in areas where strip-transect surveys had previously documented little or no tortoise sign (Berry 1984). Plots were located in areas considered to have been the least disturbed representative habitats within the desert ecosystems (e.g., Mojave Desert, Colorado Desert, etc.). Several plots on which few tortoises were found have been discontinued (K.H. Berry, pers. comm. 2003). Sixty-day plot surveys began in California, in Nevada and Utah in 1981, and in Arizona in 1987. Only a subset of plots has been surveyed each year, depending on funding, and fixed survey intervals have not been maintained (Table 1).

Table 4.1. Study plots established to study desert tortoise. A number (0 or 1) indicates that data were taken at this plot. A zero indicates that the data are not available, and a one indicates that data were available for analyses in this report.

Study Site	State	71	76	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03
Southern Argus	CA	0																											
Fremont Valley	CA		0		0		1						1				1										0		
DTNA (interior)	CA				1			1						1				1				1						0	
DTNA (inter. Center)	CA				1						1				1				1				0					0	
Fremont Peak	CA		1			1					1				1				1										
Kramer Hills	CA					1		1					1				1				1								
Stoddard Valley	CA						1						1				1												
Lucerne Valley	CA					1						1				1				1									
Johnson Valley	CA					1						1				1				1									
Shadow Valley	CA			0										1				1										0	
Ivanpah Valley	CA				1							1				1				1								0	
Fenner Valley (Goffs)	CA		0			1			0	0		0				1				1						1			
Ward Valley	CA					1							1				1				1							0	
Chemehuevi	CA		0	0	1			1						1				1							0				
Chuckwalla Valley	CA					1							1				1												
Chuckwalla Bench	CA		0	0	1			1						1		1		1				0							
Last Chance	NV					0																							
Sheep Mountain	NV				1					1								1			1								
Piute Valley	NV				0				0				1		1					1									
Christmas Tree	NV										1						1			1									
Coyote Spring	NV											1						1			1								
Gold Butte	NV											1				1				1									
Sand Hollow	NV														1					1									
Mormon Mesa	NV														1					1									
Trout Canyon	NV												1					1											
Eldorado Valley	NV																			1									
LMNRA																													
Tassi	NV																					0							
Road 152	NV																				0					0			
Road 149	NV																				0								
Road 60	NV																				0			0					
Road 58	NV																				0		0						0
Road 42	NV																						0				0		
River Mountains	NV																				1		0	1				1	
Pinto Valley	NV																				0								
Overton	NV																					1				1			
Lake Las Vegas	NV																					0							
Grapevine	NV																	1	1	1	0		0	0	0	0			
Government Wash	NV																					0							
Dupont Mine	NV																				0								
Cottonwood	NV																	1	1	1	0	0	0	0	0	0			
Cat Claw	NV																						0						
Bitter Springs	NV																					0	0						0
Pakoon Basin	AZ																0												
Virgin Slope	AZ																	1					1						
BDS Exclosure	AZ														0							1					0		
Littlefield	AZ												0						0					1				1	
City Creek	UT													1						1									
Woodbury-Hardy	UT						1					1						1						1					
Beaver Dam Slope	UT																1												

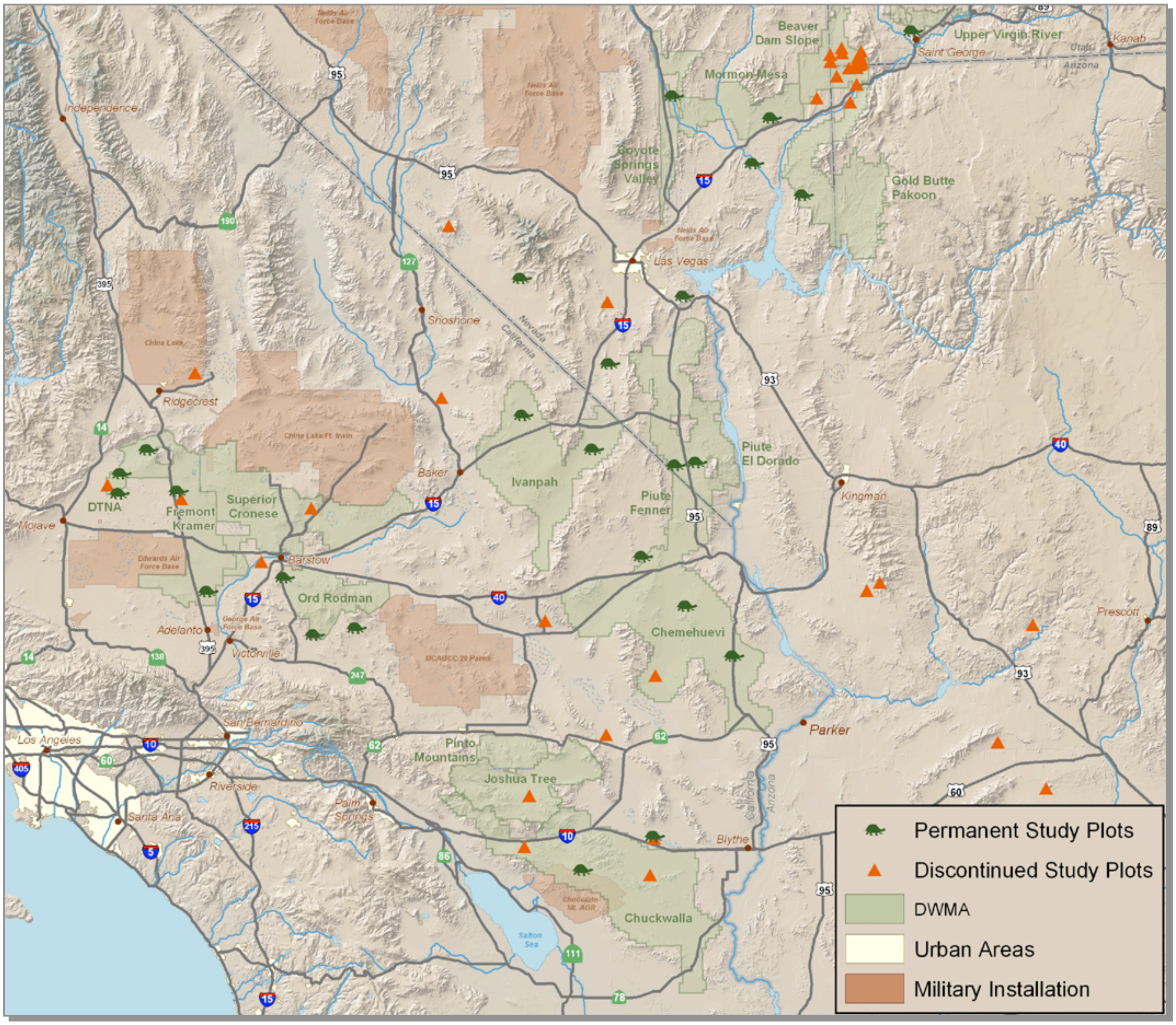
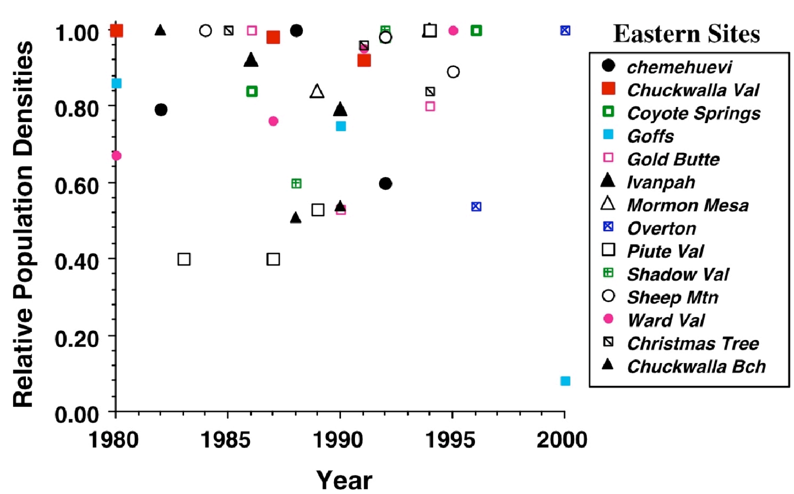


Fig. 4.1. Locations of permanent study plots for desert tortoise.

Sites sampled for an extended period and from which data were used in the original recovery plan can be divided into those in the eastern and western part of the tortoise range (this treatment of data was done in the original recovery plan). When the 1994 recovery plan was written, there were population declines in the Western Mojave. This downward trend appears unabated. There is now a guarded concern for populations in the East Mojave, particularly due to a single recent data point at the Goffs site. This concern has highlighted the need for more data to assess the importance of data points that could be outliers or indicators of new trends. In these areas, tortoises appear to be affected by various combinations of cumulative threats, not one particular threat.

Table 4.2. Study plots from which data have been used to assess trends in population size in the original recovery plan.

Eastern	**Western**
Chemehuevi Valley	Desert Tortoise Natural Area (Interior)
Chuckwalla Bench	Desert Tortoise Natural Area (Visitors Center)
Chuckwalla Valley	Fremont Valley
Ivanpah Valley	Fremont Peak
Upper Ward Valley	Johnson Valley
Christmas Tree	Kramer Mountains
Coyote Springs	Lucerne Valley
Gold Butte	Stoddard Valley
Piute Valley	
Sheep Mountain	
Trout Mountain	



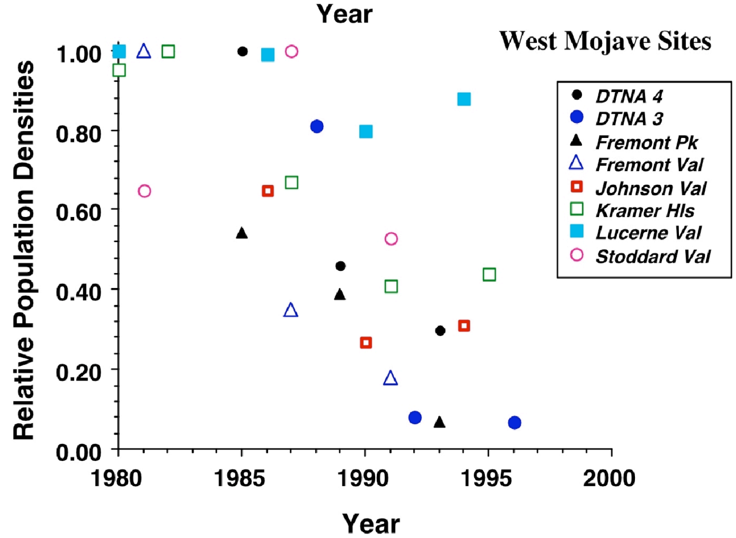


Fig. 4.2. Trends in relative population densities for desert tortoise in the eastern and western plot sites.

The plots, and the data gleaned from them, were extremely valuable in identifying the original problems with tortoises populations declining. Similarly, they remain important because of their historic data. However, there are also many problems with using permanent plots to determine population trends:

- Plots cover a small percentage (0.2%) of critical tortoise habitat, though plots are separated far enough that tortoises from one plot cannot move to another.
- Plots are neither randomly placed in critical habitat, nor are they placed to address hypotheses concerning threats or management actions (e.g., highway fencing, removing grazing, allowing fragmentation due to urbanization, etc.).
- Replication of plots within years in inadequate for comparison.
- Sample sizes of census years are largely inadequate to yield enough statistical power to perform a regression of trends in any particular plot.
- Several plots were abandoned early in the process because they had low tortoise counts. This creates a bias for analysis of trends.
- Data from plots violate assumptions in mark-recapture techniques and detectability of tortoises was not evaluated as part of the analyses.

4.1.1.1.1 Argument for stopping the use permanent plots -

- Choice of plots was not hypothesis driven and not random.
- The spacing of plots is different in different places and the spacing may not produce needed sensitivity to detect changes.

4.1.1.1.2 Argument to retain permanent plots -

- Long- term capture/recapture data from plots has the tremendous potential for looking mechanisms of trends and asking size-class survivorship questions.
- If plots were dissected allowing data to be parsed out from individual grids there would be more power to determine which threats are most important.

4.1.2 Transect Methods for Density Estimates

In addition to the data taken from the mark-recapture surveys on permanent study plots there have been several transect methods used to estimate the relative presence of tortoises, especially in the west Mojave. Prior to, but especially in support of, the West Mojave Plan (Citation), many transects were surveyed with the goal of measuring tortoise sign in the critical habitat units (CHUs) that are located in the Western Mojave Recovery Unit, especially in the Fremont-Kramer, Superior-Cronese, and Ord-Rodman CHUs. These data provide a more representative sample of these areas than do the permanent study plots, and therefore make spatial analyses possible, which we have done for the purposes of this report in the form of nearest neighbor cluster analyses.

During a workshop in February 1995 in Reno, NV (sponsored by the Biological Resources Research Center at the University of Nevada, Reno) on tortoise monitoring, tortoise biologists, statisticians, and monitoring experts reviewed previous methods used to monitor tortoise populations and possible methods to use in the future. At this workshop, the method of Distance Sampling" (Buckland et.al.,1993) was introduced as a way to mitigate the problems of the permanent study plots. At a second meeting in Laughlin, NV in October 1998, the Management Oversight Group (MOG) proclaimed Distance Sampling to be the method of choice for censusing desert tortoise populations. In June 1999, the MOG endorsed the use of Distance Sampling using program "Distance" as the method that is to be employed in range wide sampling of desert tortoise populations. However, the appropriateness of the technique for desert tortoise was, and remains, contentious.

In January 2001 a monitoring workshop was held in Las Vegas, Nevada, to explain the sampling techniques that would be used in 2001 to conduct the first years effort of Line Distance Sampling. This meeting was attended by agency and contractor personnel. A handbook was prepared by the Desert Tortoise Coordinator provided in March 2001 to serve as the manual for conducting the distance sampling in 2001. In March of 2001, two training workshops were conducted. Each of the two (four day) workshops possessed approximately 40 personnel. These training workshops provided practice of the Distance Sampling techniques using the styrofoam tortoises models (styrotorts) placed in natural habitats near Jean, Nevada. This technique had been used as part of an earlier demonstration workshop conducted in early October 1998, (Anderson et.al. 2001). Finally, the tortoise transects in 2001 were sampled by Chambers Group, Kiva Biological Consultants, and Mojave National Preserve, the University of Nevada, Reno, and the Utah Division of Wildlife Resources.

In 2001 the first range-wide transects with the goal of density estimation using the distance sampling technique (Buckland et al. 2001) were surveyed. Data from these transects can be used to calculate density estimates at several scales (e.g for each DWMA or Recovery Unit)(Anderson et al. 2001).

Density estimates for the 2001 distance sampling for the West Mojave indicate approximate densities of 7.3 tortoises/km^2 (95% CI 5 – 10) for the Fremont-Kramer DWMA, and 9.6 tortoises/km2 (95% CI 7 – 13) for the Ord-Rodman DWMA. These numbers are relatively comparable to those given for permanent study plots near the same two DWMAs (DTNA Interior for 2002 = 2 tortoises/km^2 (95% CI 1-4), Fremont Valley for 2001 = 5 tortoises/km^2 (95% CI 2-9). However, the transect sampling design was flawed in such a way for subsequent years (2002 and 2003) that the samples cannot be considered representative of the DWMAs as a whole. Therefore, density estimates for 2002 and 2003 are not considered herein, and cannot contribute toward knowledge of current status.

Still, the data provided by transects sampled in 2001 provide a great source of information for spatial analyses. For example we found that the spatial data from both the relative sign, and distance sampling transects could be used to understand better the information regarding the declining density estimates of tortoises as provided by the permanent study plots, especially in the West Mojave.

Spatial analyses on independent data sets provided insight about where within the west Mojave tortoise populations were probably in the most dire condition. Thus, new spatial analyses of transect data, in conjunction with long-term trend data are an example of how to merge information from past and current sampling efforts to inform and focus management efforts. **We recommend that integrative approaches to data synthesis and analysis be pursued in the future to ensure the greatest insight from the best available data.**

4.1.3 DTRPAC Analyses of Status and Trends

4.1.3.1 Plot Analysis Methods

Permanent study plots were used to the maximum extent possible to give the committee some insight into the range-wide status of tortoises over time.

Density estimates and confidence limits for those estimates were collected from published literature, and reports on the permanent study plots that were sampled from 1979 to 2002. Not all plots were sampled in all years, and not all data were obtainable for plots that were sampled in some years (Table on Plot Data).

Because none of the study plots by themselves are representative of a geographic area, study plots were combined as samples of larger regional areas for analysis. The areas we examined included the Recovery Units that were specified in the original recovery plan, and the Distinct Population Segments suggested by the DTRPAC (see DPS section).

Density estimates for adult tortoises (carapace lengths > 208 mm) were regressed against time (years), using the study plot as a factor, and weighted by the inverse of the magnitude of the upper confidence limit relative to the magnitude of the density estimate (Sedinger and Manly, pers. Comm.). The results of the individual effect of densities over time are presented using leverage plots to examine visually the time effect after accounting for any effect of site and in the context of the weighted model (Sall 1990). Leverage plots show, for each point, what the residual would be both with and without that effect in the model and is a general way to display the data (adult density) from the point of view of the hypothesis for that effect, in this case years (Sall 1990).

Some of the Recovery Units, or proposed Distinct Population Segments did not have sufficient PSPs contained within them to analyze, or to have enough power to provide a conclusive analysis. For example, the Upper Virgin River recovery unit, and proposed DPS contains only one PSP (City Creek), for which we have density estimates for only 1988 and 1994. No analyses were conducted for this RU/DPS. In addition, the Eastern Colorado Recovery Unit had two PSPs, and the Northern Colorado recovery unit had only one PSP.

The West Mojave, and the Upper Virgin River Recovery Units contain the same set of permanent study plots as the proposed West Mojave and Upper Virgin River Distinct Population Segments, and therefore new analyses were not conducted for the DPSs.

4.1.3.2 Results from plot analyses by Recovery Unit

4.1.3.2.1 Results from plot analyses by Recovery Unit (West Mojave)

The West Mojave Recovery Unit included the DTNA Interior, DTNA Interpretive Center, Fremont Peak, Fremont Valley, Johnson Valley, Kramer Hills, Lucerne Valley, and Stoddard Valley Permanent Study Plots **(Fig. *4.3*).**

The overall analysis was significant ($F_{8,25} = 7.2$, $P < 0.0001$), and the year effect yielded a significantly negative trend in adult density estimates over time ($F_{1,25} = 20.52$, $P = 0.0001$, Fig. 4.4). There was also a significant contribution of site to the model ($F_{7,25} = 4.46$, $P = 0.003$). This analysis indicates that, taken together, the permanent study plots located within the West Mojave Recovery unit are still declining, as was suggested in the Recovery Plan (Recovery Plan, Appendix C, page C10, Figure C5), indicating that recovery actions that have been implemented since the plan have not resulted in the reversal of this declining trend.

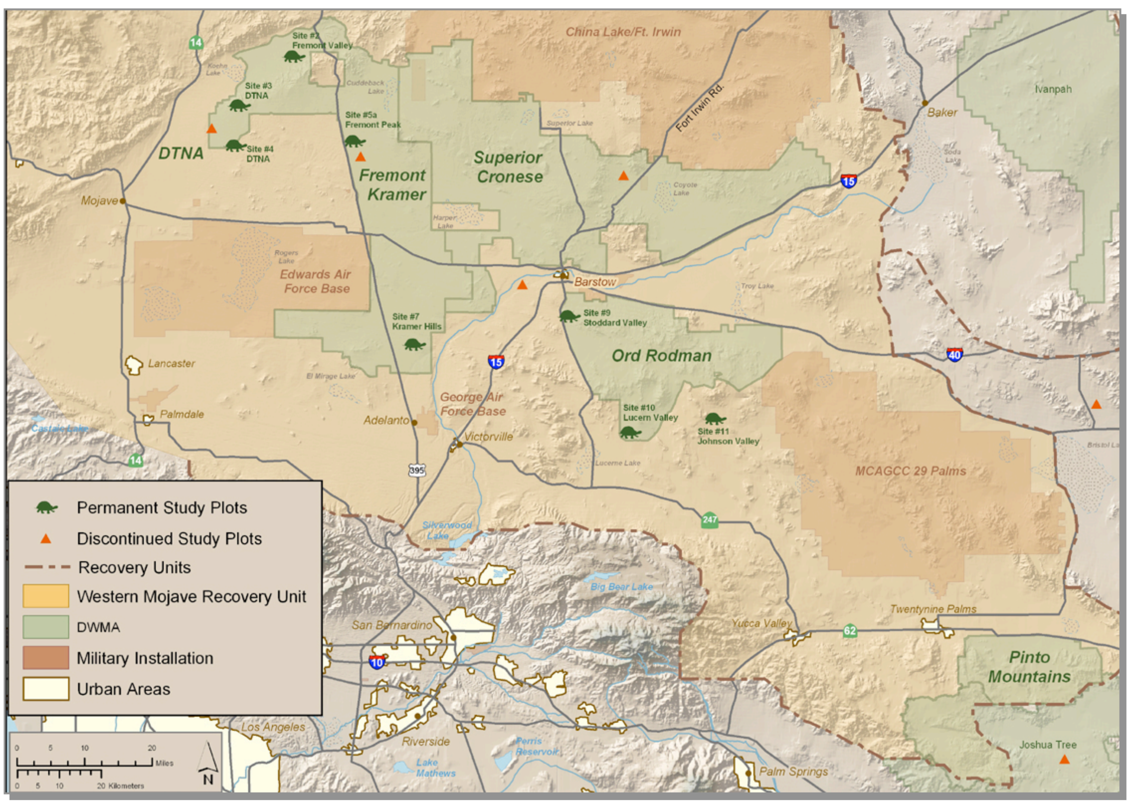
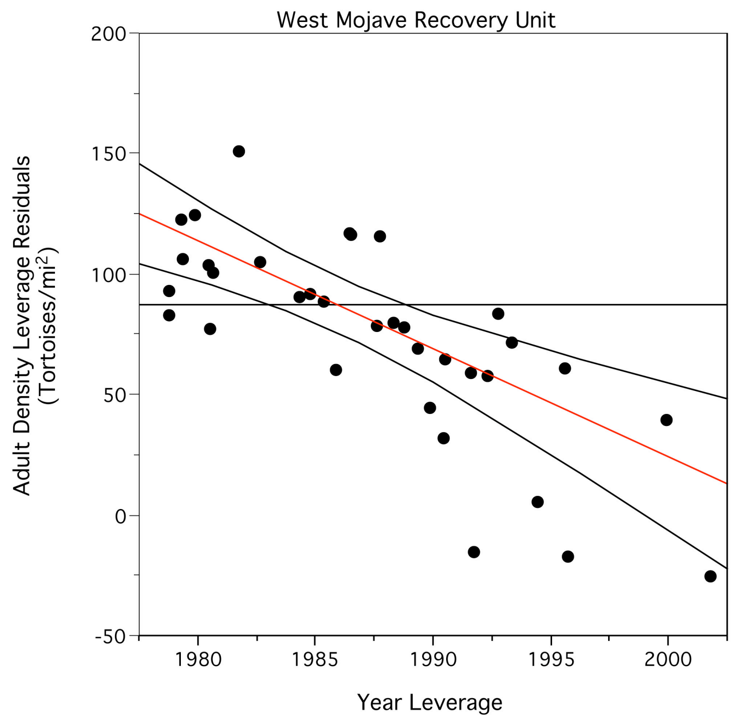


Fig. 4.3. Permanent study plots contributing to the West Mojave Recovery Unit analysis. Permanent study plots are indicated by the red circles.

Fig. 4.4 Leverage Residual plot of the year effect in the weighted ANOVA analysis for the West Mojave Recovery Unit.



4.1.3.2.2 Results from plot analyses by Recovery Unit (Eastern Colorado)

The Eastern Colorado Recovery Unit contained two permanent study plots, Chuckwalla Bench, and Chuckwalla Valley (Fig. 4.6). This limits how generalizable the results from this analysis can be, and highlights one of the weaknesses of using data from permanent study plots to discern long-term trends for management areas, whether they are Recovery Units or Distinct Population Segments. The overall model for the Eastern Colorado Recovery Unit was significant ($F_{2,6} = 21.0$, $P = 0.002$). The effect of site ($F_{1,6} = 19.18$, $P = 0.005$) was significant, as was the effect of year ($F_{1,6} = 20.24$, $P = 0.004$).

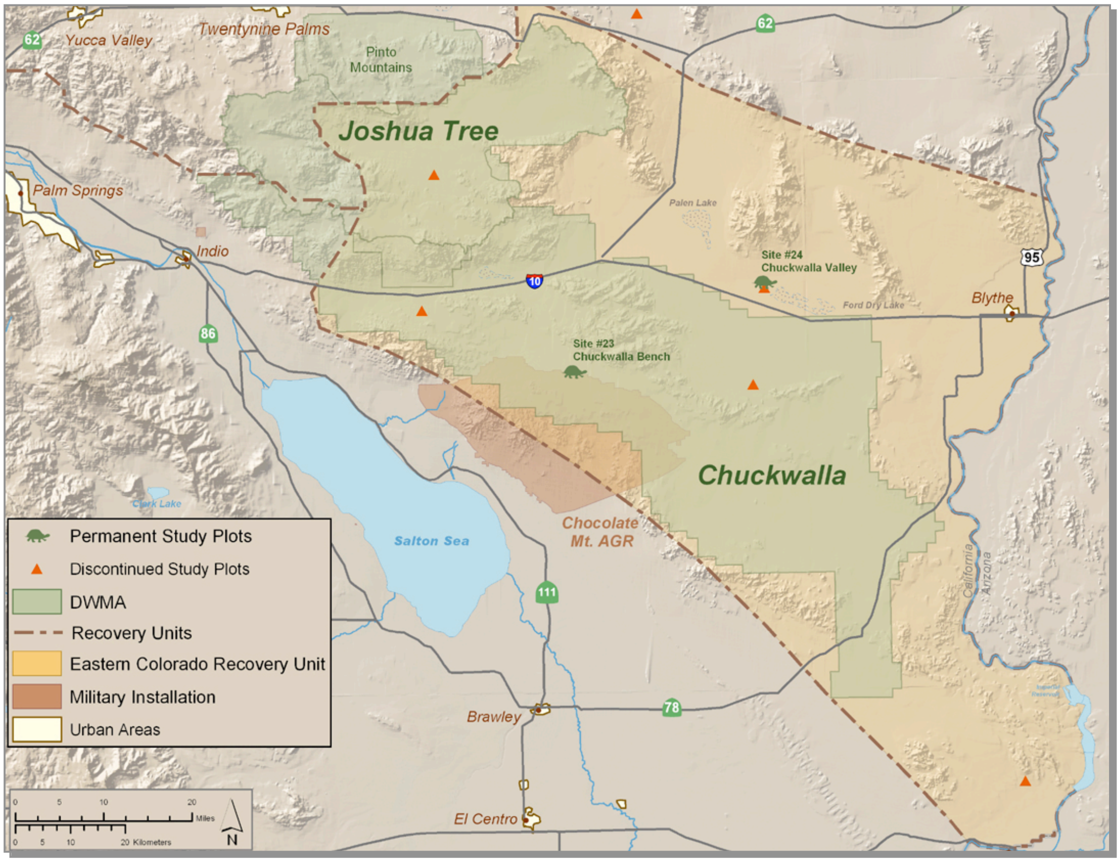
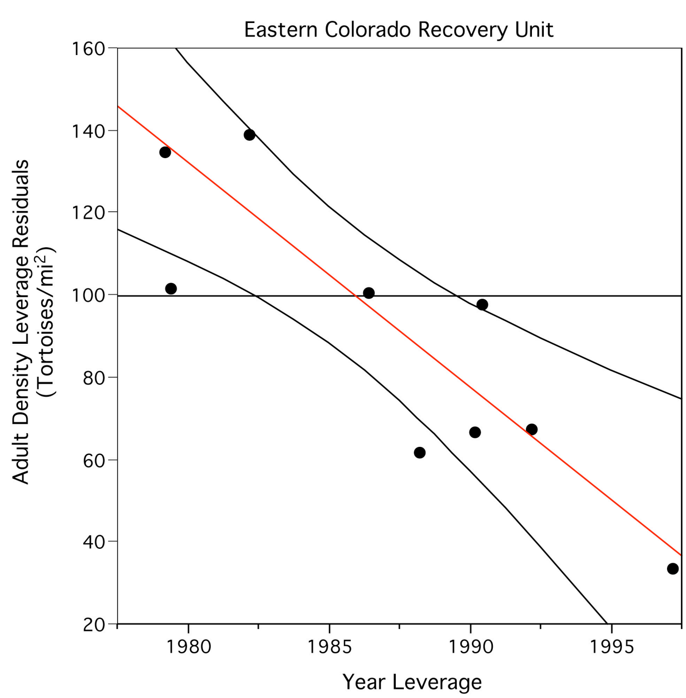


Fig. 4.5 Permanent study plots contributing to the Eastern Colorado Recovery Unit analysis. Permanent study plots are indicated by the red circles.

Fig. 4.6 Leverage Residual plot of the year effect in the weighted ANOVA analysis for the Eastern Colorado Recovery Unit.



4.1.3.2.3 Results from plot analyses by Recovery Unit (Northern Colorado)

There was only one PSP represented in the Northern Colorado recovery unit, which was the Chemehuevi PSP (Fig. 4.8). Therefore no analysis was generated for this recovery unit.

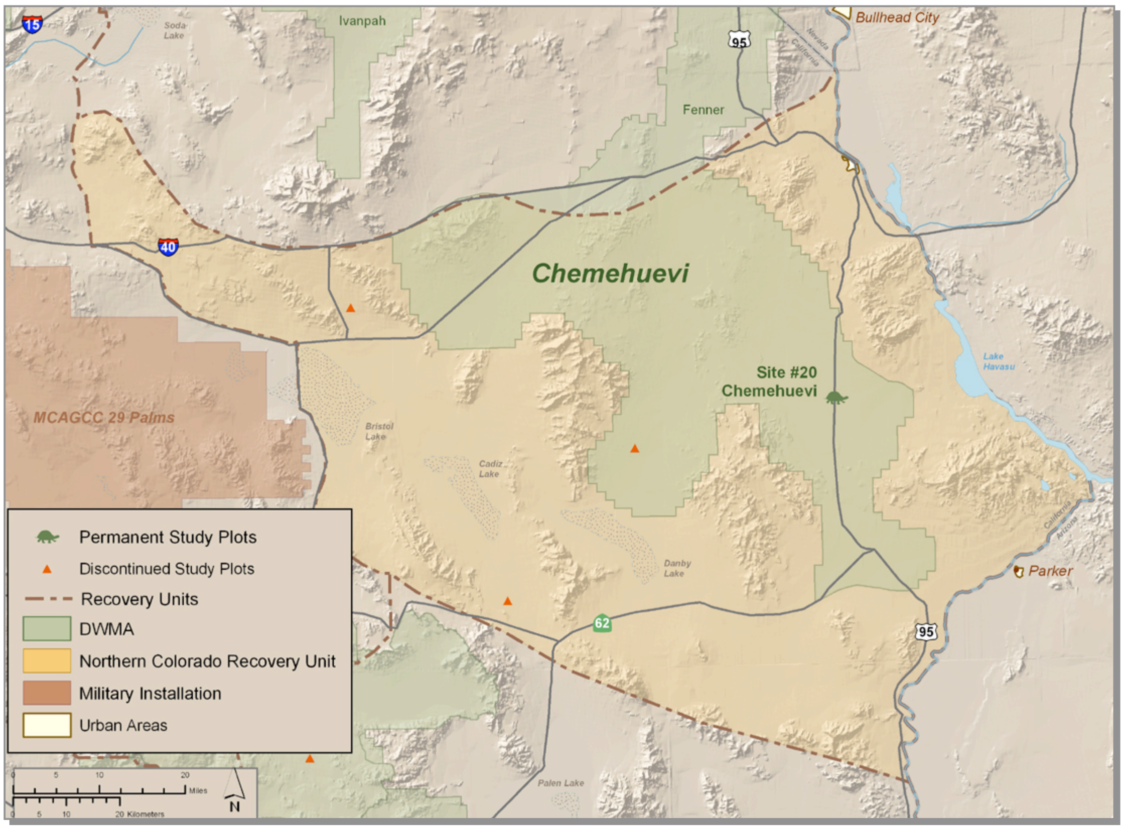


Fig. 4.7 Permanent study plots contributing to the Northern Colorado Recovery Unit analysis. The Chemehuevi permanent study plot is indicated by the red circle.

4.1.3.2.4 Results from plot analyses by Recovery Unit (East Mojave)

The East Mojave Recovery Unit contains the Christmas Tree, Goffs, Ivanpah, Shadow Valley, and Ward Valley permanent study plots (Fig. 4.8).

The overall analysis for the East Mojave Recovery Unit was significant ($F_{5,14} = 10.89$, $P = 0.0002$). This result was entirely due to the significance of the site effect ($F_{4,14} = 13.0$, $P = 0.0001$), This indicated that there was no trend in adult density estimates over time.

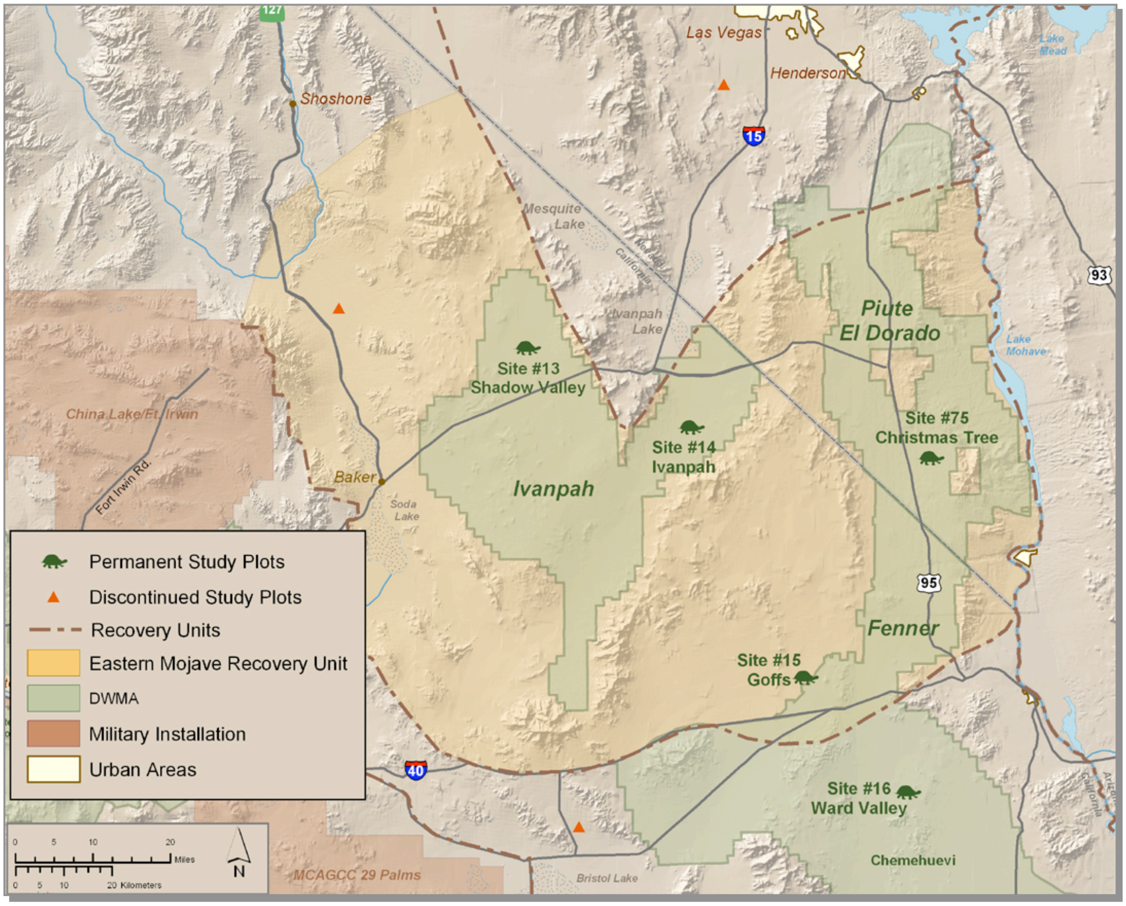


Fig. 4.8 Permanent study plots contributing to the East Mojave Recovery Unit analysis. The permanent study plots are indicated by the red circles.

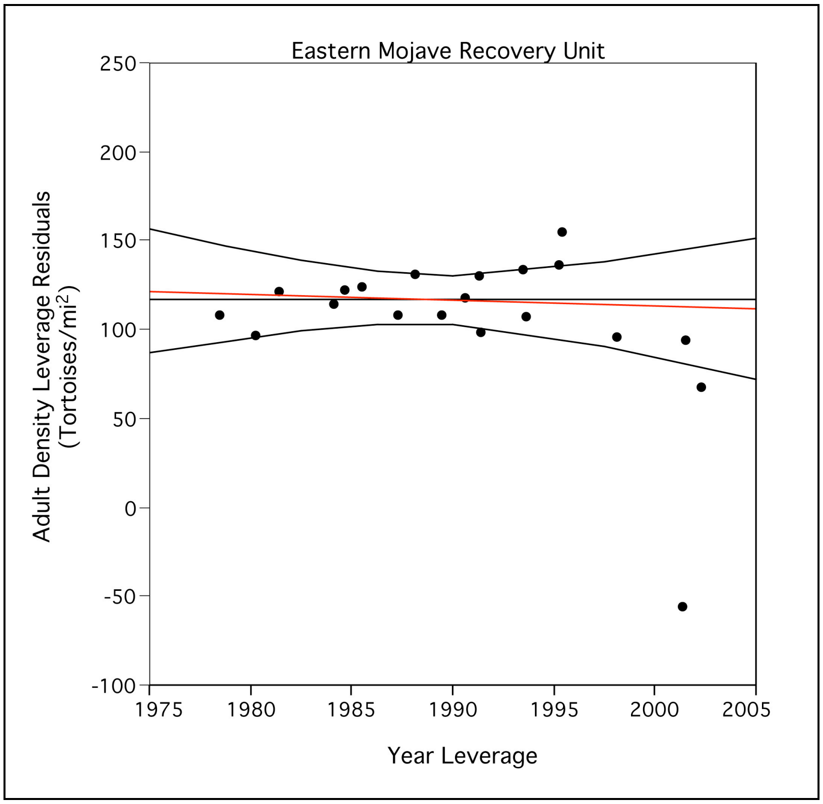


Fig. 4.9 Leverage Residual plot of the year effect in the weighted ANOVA analysis for the East Mojave Recovery Unit.

4.1.3.2.5 Results from plot analyses by Recovery Unit (Northeast Mojave)

The Northeast Mojave Recovery Unit contained the Coyote Springs, Gold Butte, Mormon Mesa, Overton, Piute Valley, River Mountain, Sheep Mountain, and Trout Canyon permanent study plots (Fig. 4.10).

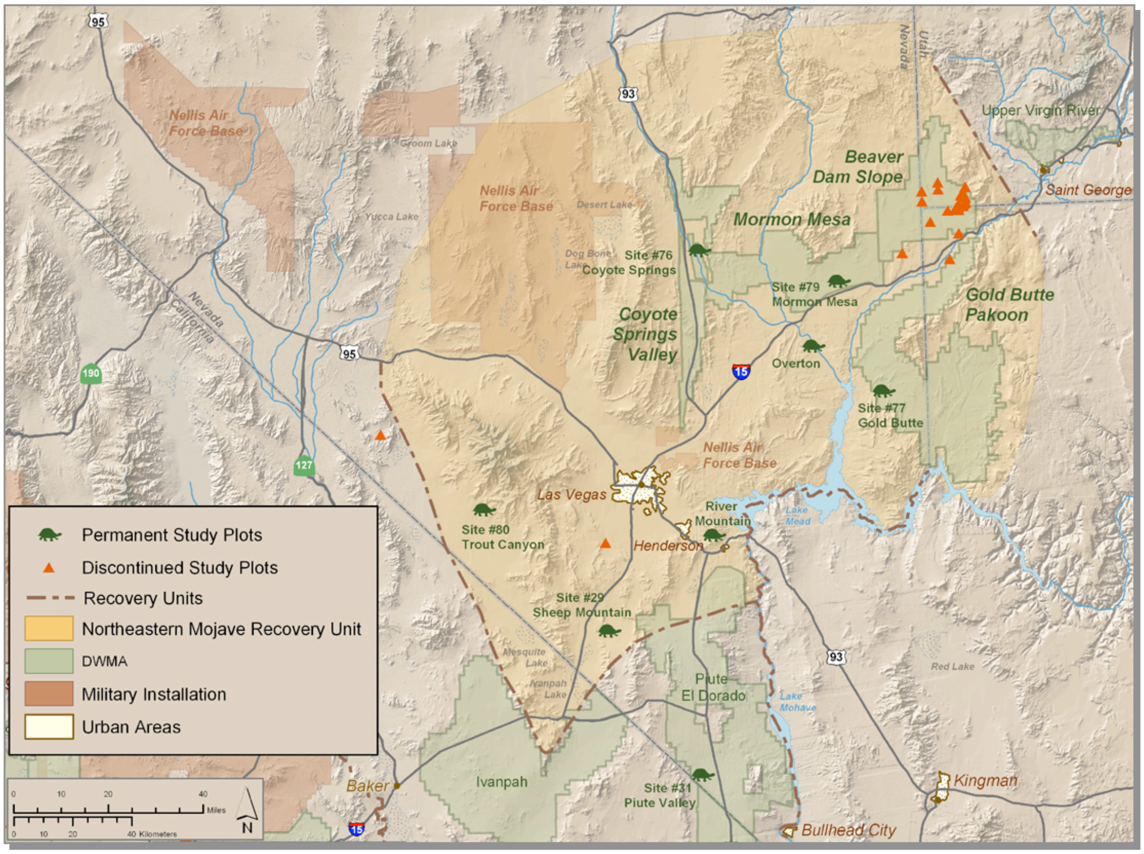


Fig. 4.10 Permanent study plots contributing to the Northeast Mojave Recovery Unit analysis. The permanent study plots are indicated by the red circles.

The overall analysis was significant ($F_{8,11} = 5.46$, $P = 0.006$), which was entirely due to the effect of site ($F_{7,11} = 6.24$, $P = 0.004$). There was no significant trend in adult density over time ($F_{1,11} = 0.21$, $P = 0.65$).

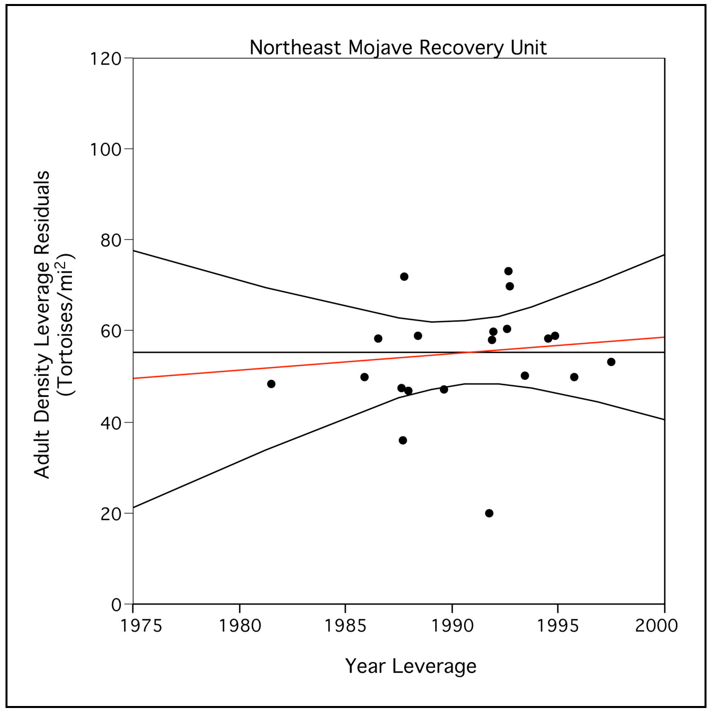


Fig. 4.11 Leverage Residual plot of the year effect in the weighted ANOVA analysis for the Northeast Mojave Recovery Unit.

4.1.3.2.6 Results from plot analyses by Recovery Unit (Upper Virgin River)

There was only one PSP represented in the Upper Virgin River recovery unit (City Creek), and therefore no analysis was generated for this recovery unit.

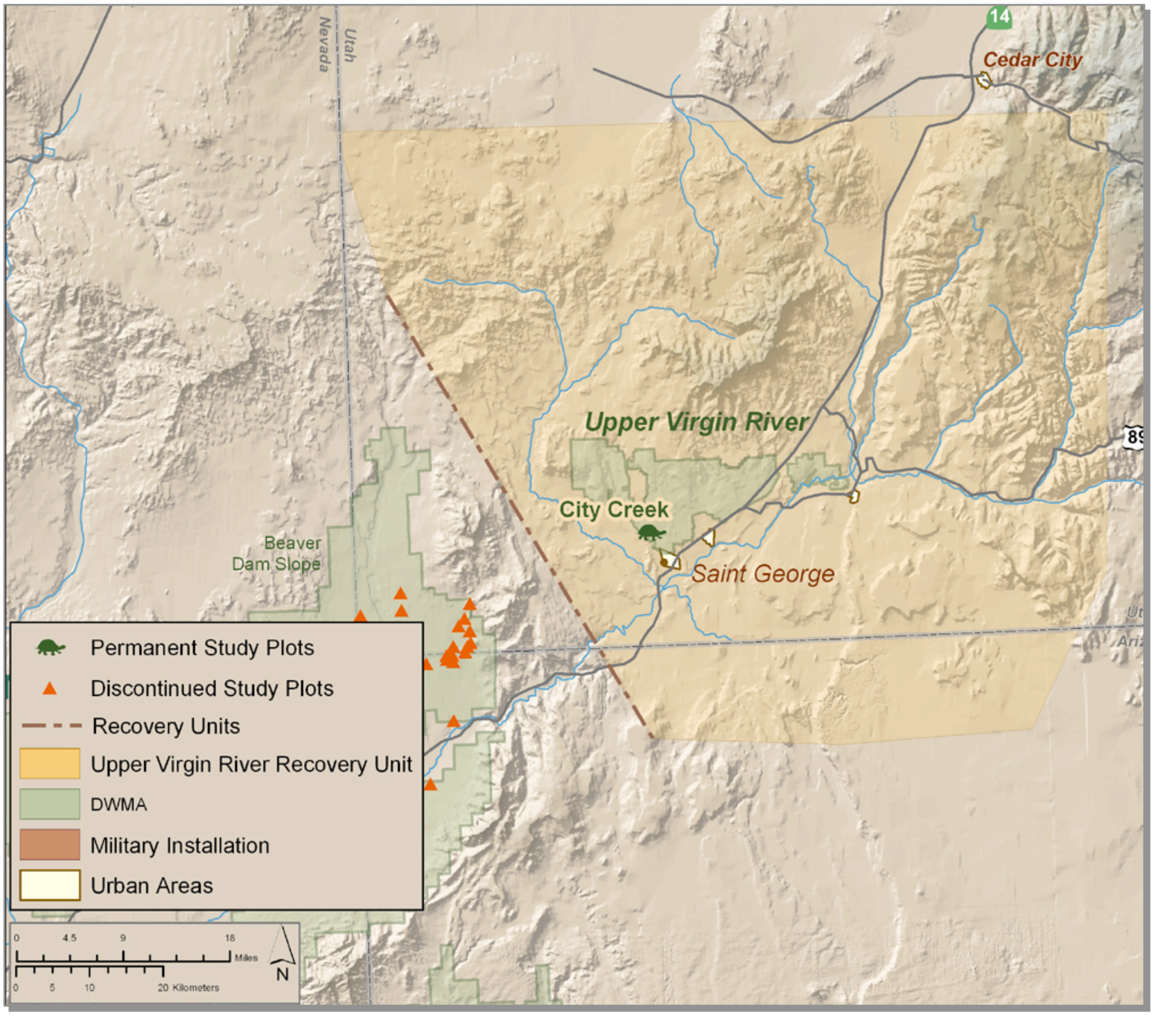


Fig. 4.12 Permanent study plots contributing to the Upper Virgin River Recovery Unit analysis. The permanent study plot is indicated by the red circles.

4.1.3.3 Results from plot analyses by Distinct Population Segment

4.1.3.3.1 Results from plot analyses by DPS (West Mojave)

The permanent study plots that are included in the proposed West Mojave distinct population segment are the same as those in the West Mojave Recovery Unit, and are therefore identical. The map, and results for the recovery unit can be referenced in the recovery unit section.

4.1.3.3.2 Results from plot analyses by DPS (Eastern Mojave and Colorado)

The Eastern Mojave and Colorado distinct population segment contains the Chemehuevi, Christmas Tree, Chuckwalla Bench, Chuckwalla Valley, Goffs, Piute Valley, Ward Valley permanent study plots (Fig. 4.13).

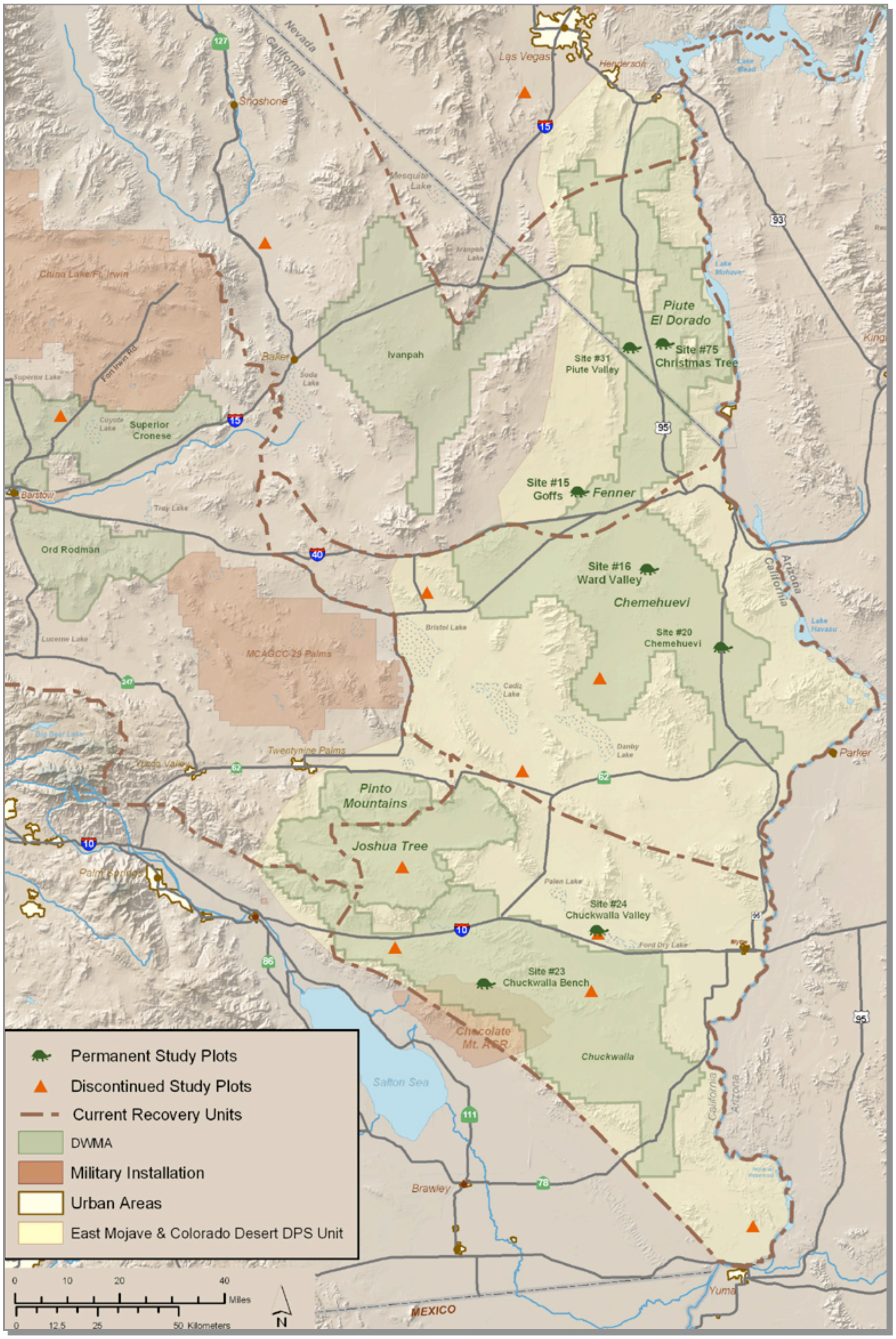


Fig. 4.13 Permanent study plots contributing to the Eastern Mojave and Colorado Distinct Population Segment analysis. The permanent study plots are indicated by the red circles.

The overall analysis was significant ($F_{7,20} = 11.89$, $P < 0.0001$), which was entirely due to the effect of site ($F_{6,20} = 13.46$, $P < 0.0001$). There was no significant trend in density estimates over time ($F_{1,20} = 2.22$, $P = 0.15$).

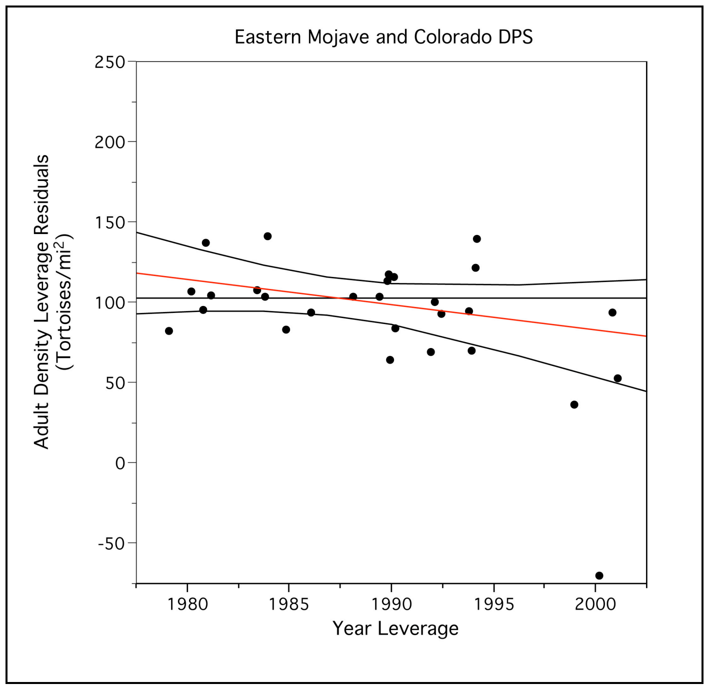


Fig. 4.14 Leverage Residual plot of the year effect in the weighted ANOVA analysis for the Eastern Mojave and Colorado Distinct Population Segment.

4.1.3.3.3 Results from plot analyses by DPS (Northeast Mojave)

The Northeast Mojave distinct population segment contains the Ivanpah, Shadow Valley, Sheep Mountain, and Trout Canyon distinct population segments (Fig. 4.15).

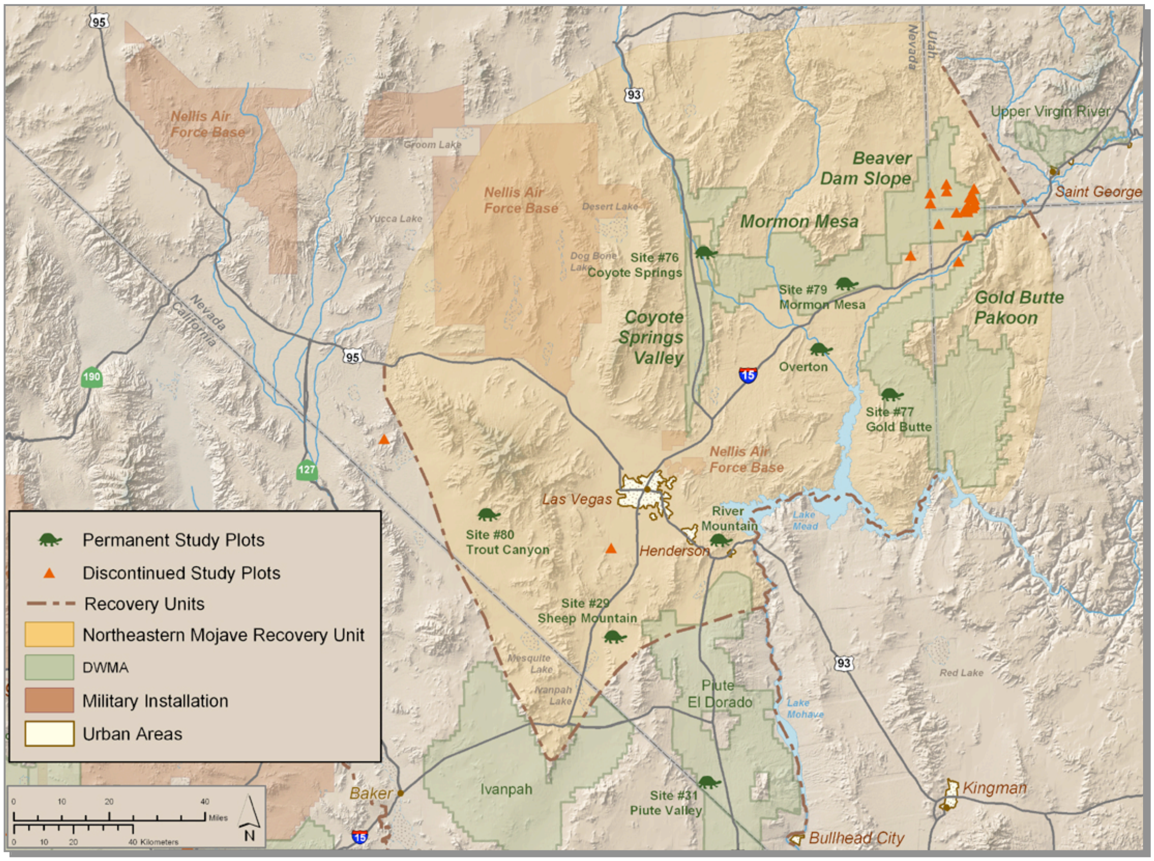


Fig. 4.15 Permanent study plots contributing to the Northeast Mojave Distinct Population Segment analysis. The permanent study plots are indicated by the red circles.

The overall analysis was significant ($F_{4,9} = 26.52$, $P < 0.0001$), which was entirely due to the effect of site ($F_{3,9} = 35.35$, $P < 0.0001$). There was no trend in adult densities as a function of time ($F_{1,9} = 0.06$, $P = 0.82$).

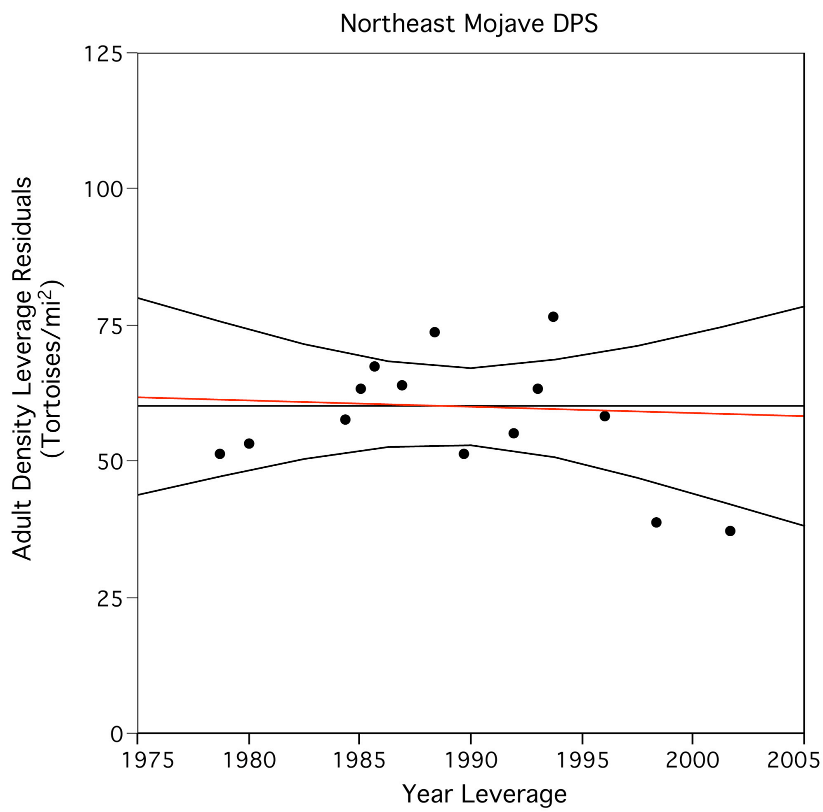


Fig. 4.16 Leverage Residual plot of the year effect in the weighted ANOVA analysis for the Northeast Mojave Distinct Population Segment.

4.1.3.3.4 Results from plot analyses by DPS (Lower Virgin River)

The Lower Virgin River distinct population segment contains the Coyote Springs, Gold Butte, Mormon Mesa, Overton, and River Mountain permanent study plots (Fig. 4.17).

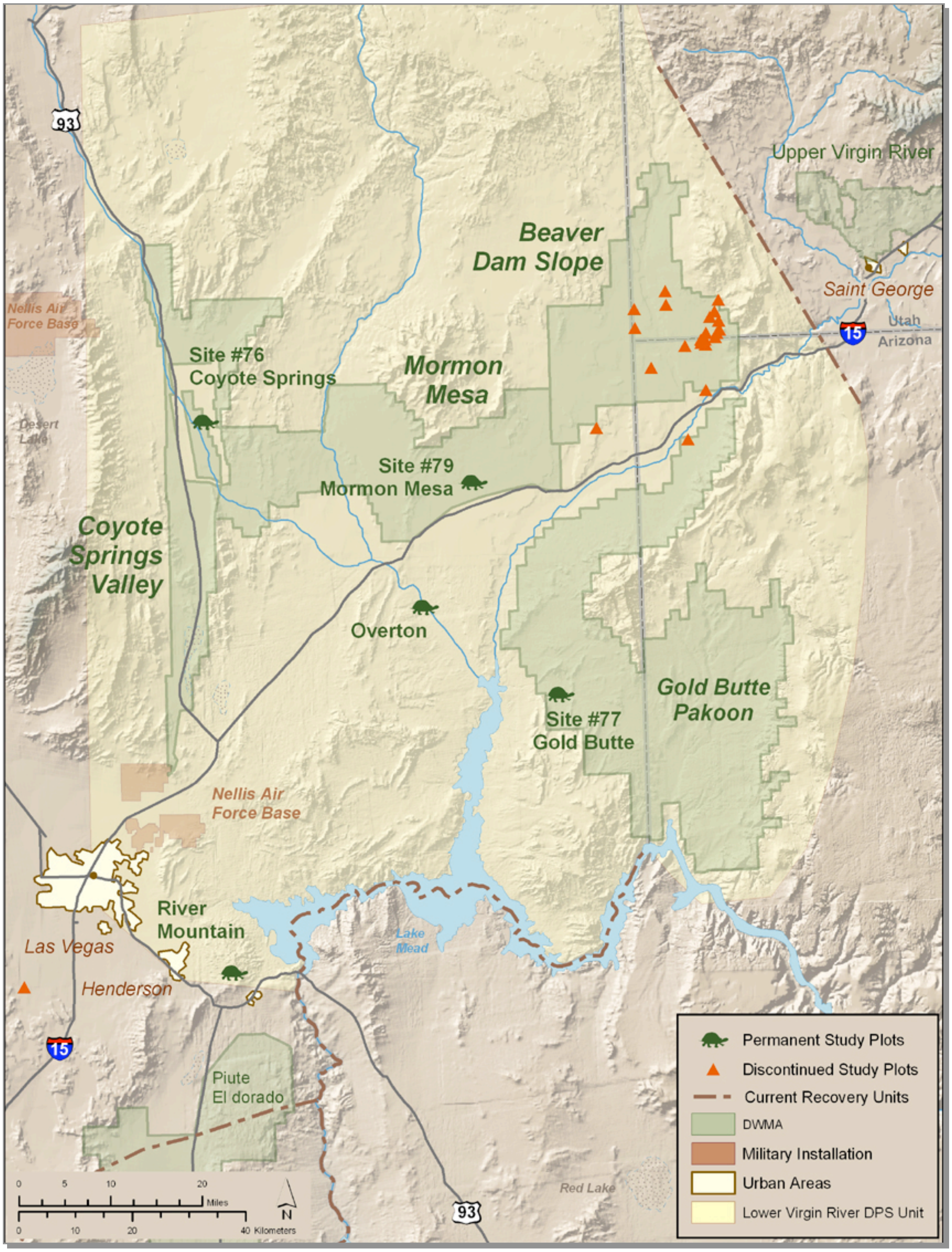
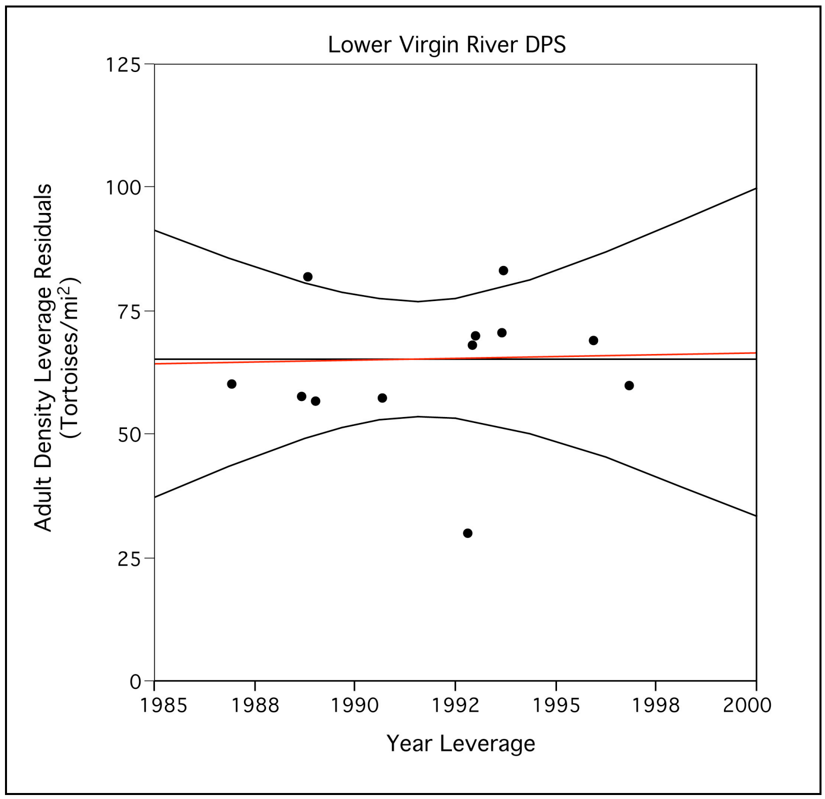


Fig. 4.17 Permanent study plots contributing to the Lower Virgin River Distinct Population Segment analysis. The permanent study plots are indicated by the red circles.

The overall analysis was not significant ($F_{5,6} = 3.7$, $P = 0.07$). Indicating that there was no effect of site, and importantly that there was no significant trend in adult tortoise density over time ($F_{1,6} = 0.29$, $P = 0.61$).

Fig. 4.18 Leverage Residual plot of the year effect in the weighted ANOVA analysis for the Lower Virgin River Distinct Population Segment.



4.1.3.3.5 Results from plot analyses by DPS (Upper Virgin River)

The Upper Virgin River DPS contains the same permanent study plot (City Creek) as the recovery unit. No analysis was conducted as per the recovery unit section.

4.1.3.4 Transect Analyses

Line transects were conducted for the years 2001-2003 by the FWS in support of the range-wide sampling of tortoises within desert wildlife management areas (DWMAs). The data from these transects are used to create estimates of tortoise density for each DWMA using the distance technique. Changes in the sampling design were made during the 2002-2003 seasons that make interpretations of the density estimates relative to current status problematic. However, there was the opportunity to ask questions of the 2001 transect data with respect to the spatial distribution of live and dead tortoises encountered on transects.

We conducted several spatial analyses to explore the spatial variation of tortoises sampled on transects. The first of these were adaptive kernel estimation analyses (REF). The purpose of these analyses was to compare the spatial distributions of live animals relative to the spatial distributions of carcasses in DWMAs.

4.1.3.4.1 Kernel Analyses

4.1.3.4.1.1 Methods for Kernel

Adaptive kernel analyses were run on observations of live and dead tortoises found on transects for adjacent DWMAs throughout the Mojave using transect data from the 2001 FWS monitoring data. Data were separated into subjective groups that appeared to create natural clusters of sampling effort. Observations from these groups were separated into two datasets, one for live observations and one for carcasses observed. Kernel analyses were conducted for the live and carcass data for each of the subjective groupings. The kernels were created using the Animal Movement Extension (v 2.04b, Hooge and Eichenlaub 2001) for ArcView 3.2 (ESRI, Redlands, CA). The smoothing factor (H) was reduced to a value below that of the default in order to constrain the kernels to areas that were closer to being contained by the sample areas. These smoothing factors were taken to be the same for the carcass and live kernels for each area, and are given for each of the kernel analyses. Separate kernel analyses were conducted for the following areas which are generally denoted by the DWMAS included therein: 1) Fremont-Kramer, Superior-Cronese, and Ord-Rodman DWMAs; 2) Chuckwalla and Pinto Mountain DWMAs; 3) Chemehuevi DWMA; 4) Ivanpah; 5) Beaver Dam Slope, Mormon Mesa, and Goldbutte-Pakoon; 6) Paiute-Eldorado Valley; and 7) Upper Virgin River.

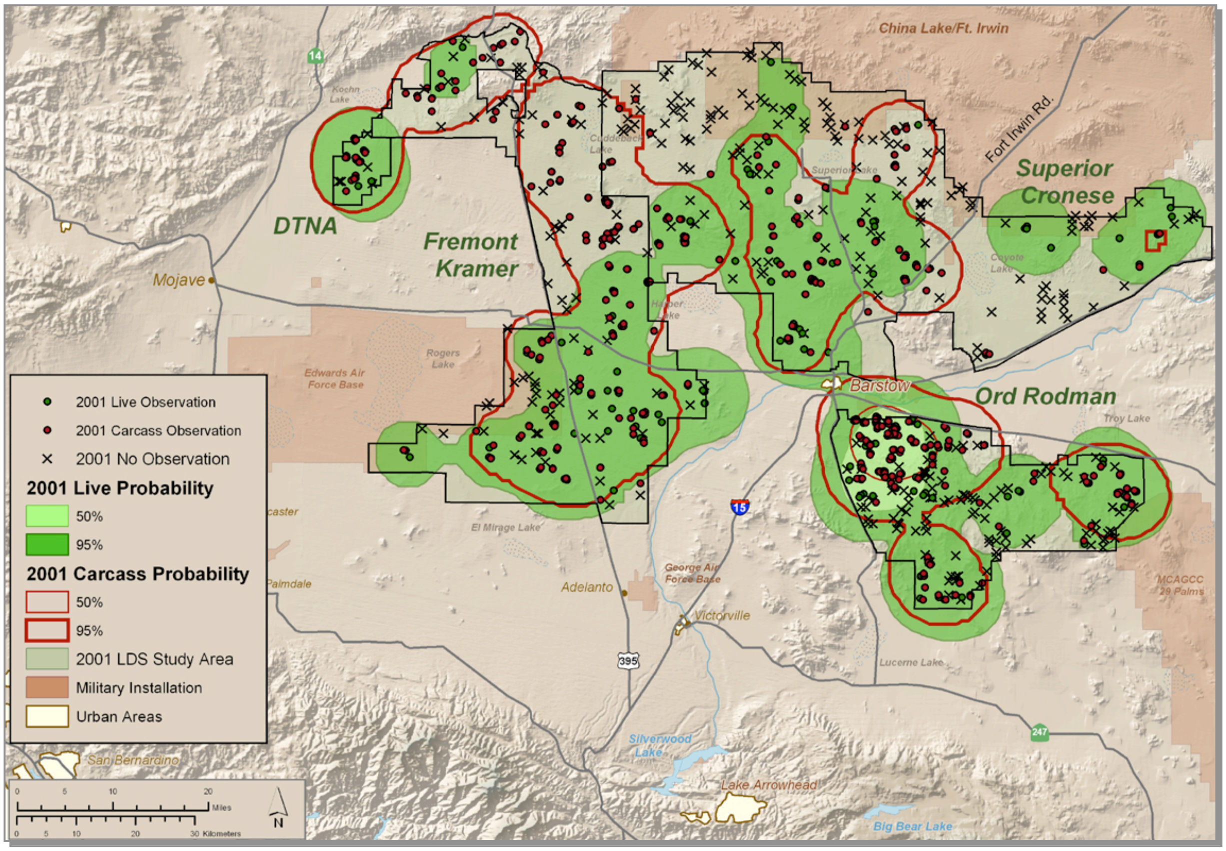


Fig. 4.19 Kernel analysis for the Fremont-Kramer, Superior-Cronese, and Ord-Rodman DWMAs. The 95% kernel for live animals is indicated by the green bondary, the 95% kernel for the carcasses found is indicated by the red boundaries. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

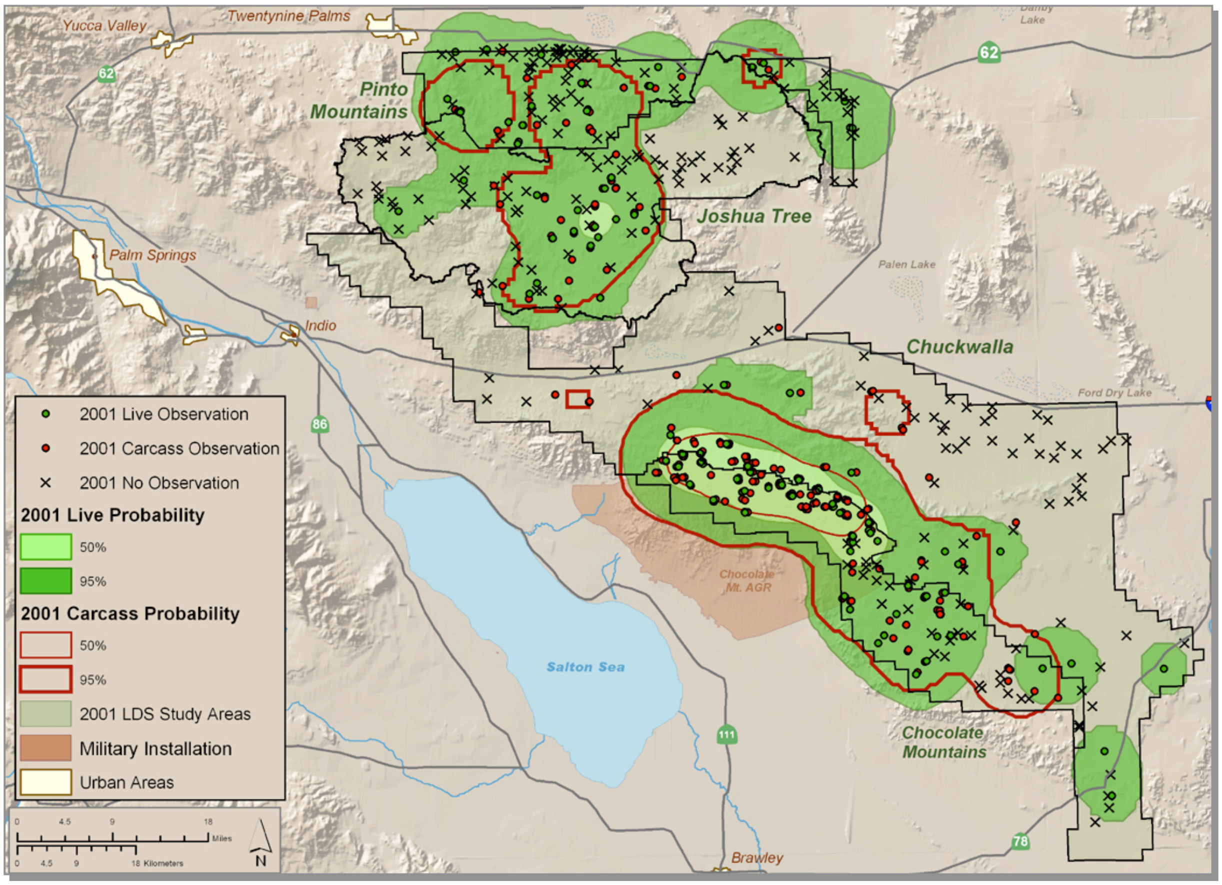


Fig. 4.20 Kernel analysis for the Chuckwalla and Pinto Mountain DWMAs. The 95% kernel for live animals is indicated by the green bondary, the 95% kernel for the carcasses found is indicated by the red boundaries. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

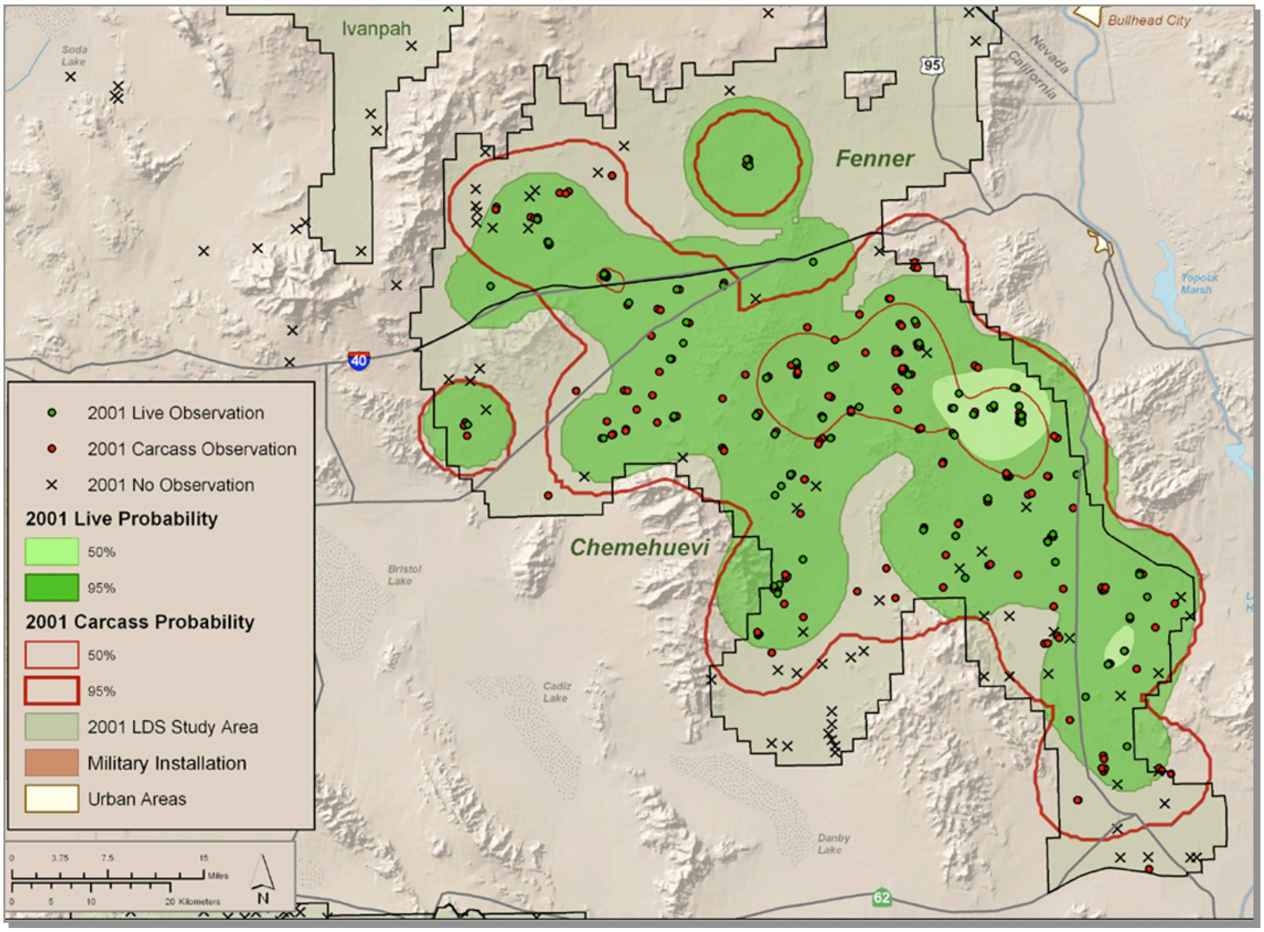


Fig. 4.21 Kernel analysis for the Chemehuevi DWMA The 95% kernel for live animals is indicated by the green bondary, the 95% kernel for the carcasses found is indicated by the red boundaries. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

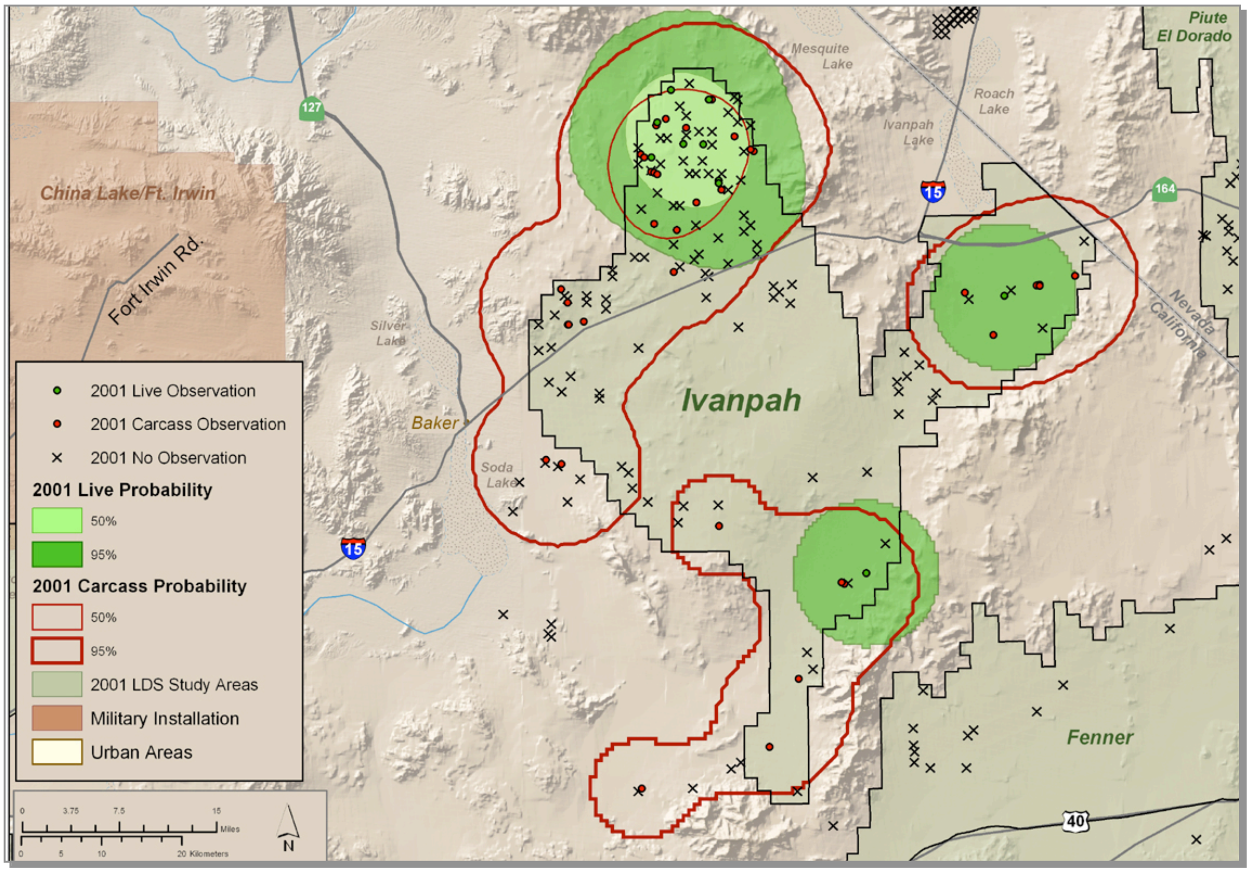


Fig. 4.22 Kernel analysis for the Ivanpah DWMA The 95% kernel for live animals is indicated by the green bondary, the 95% kernel for the carcasses found is indicated by the red boundaries. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

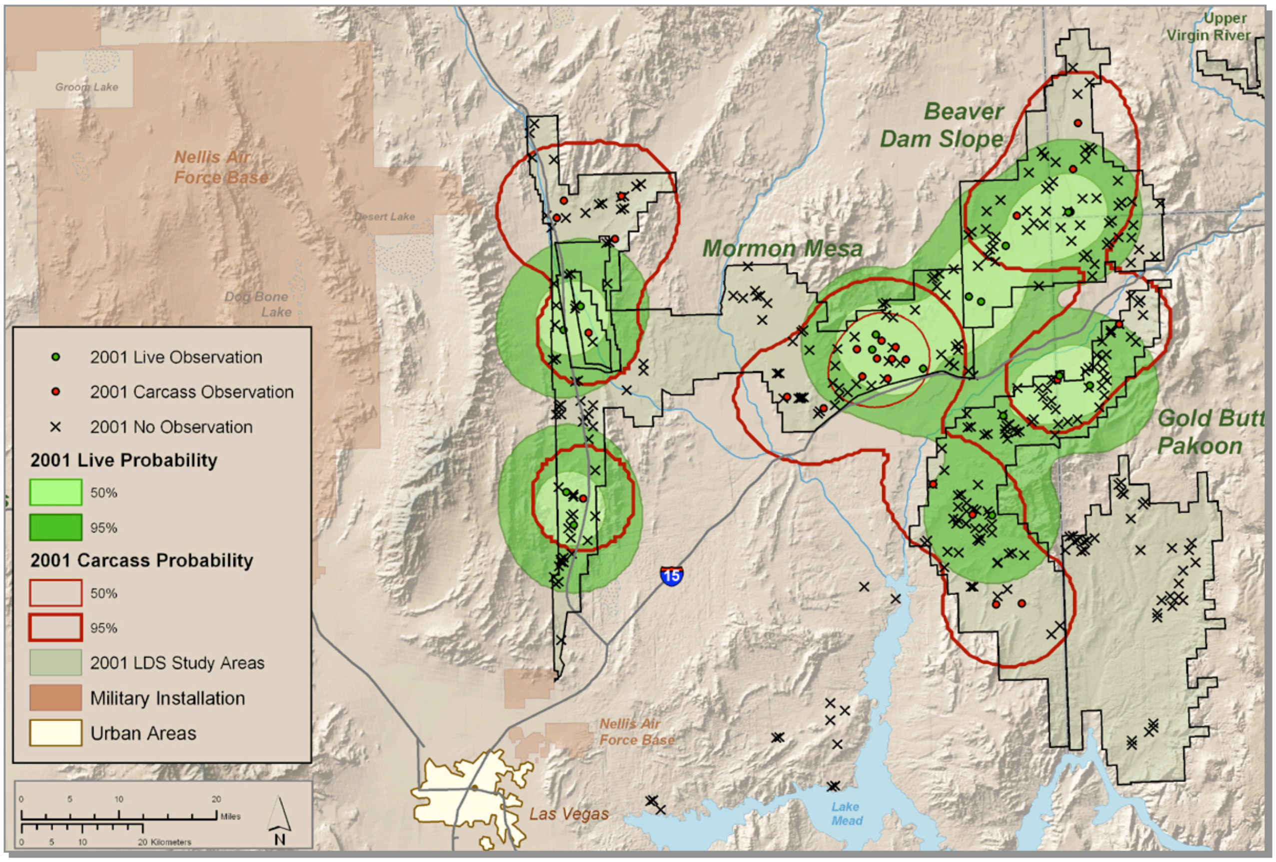


Fig. 4.23 Kernel analysis for the Beaver Dam Slope, Mormon Mesa, and Goldbutte-Pakoon DWMAs The 95% kernel for live animals is indicated by the green bondary, the 95% kernel for the carcasses found is indicated by the red boundaries. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

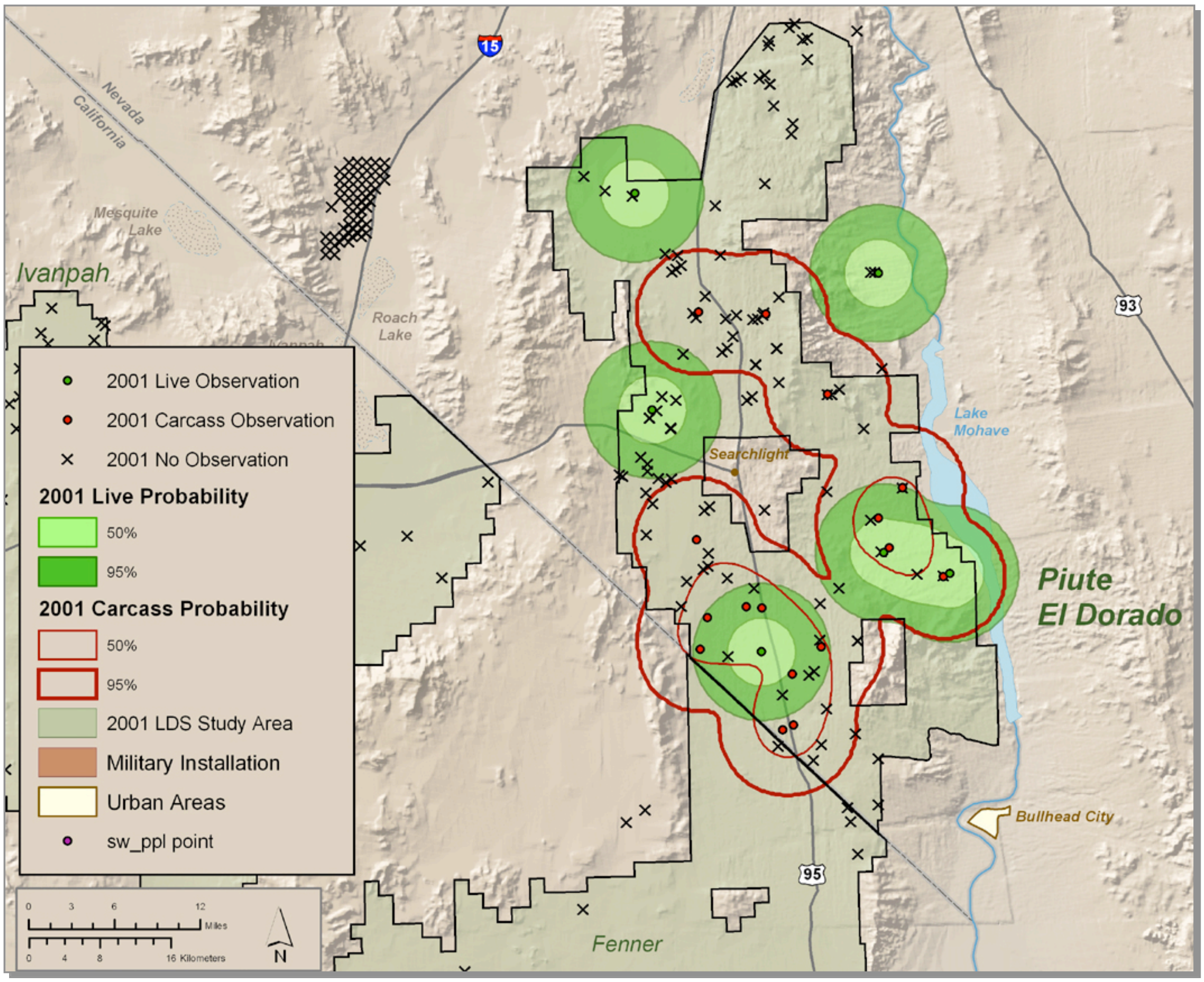


Fig. 4.24 Kernel analysis for the Paiute-Eldorado Valley DWMA. The 95% kernel for live animals is indicated by the green bondary, the 95% kernel for the carcasses found is indicated by the red boundaries. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

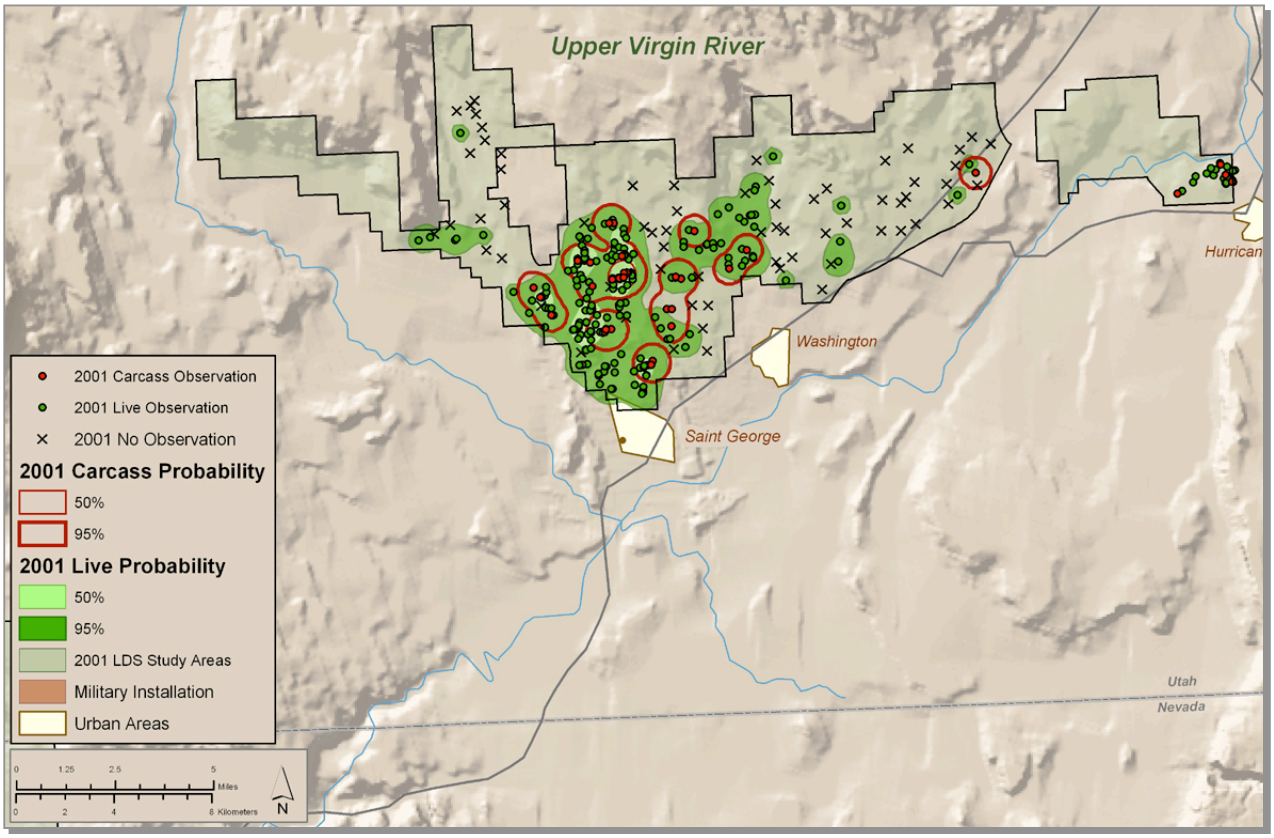


Fig. 4.25 Kernel analysis for the Upper Virgin River DWMA. The 95% kernel for live animals is indicated by the green bondary, the 95% kernel for the carcasses found is indicated by the red boundaries. Transects that were sampled for which no tortoises (live or dead) were found are indicated by the letter X on the map.

4.1.3.4.1.2 Results of Kernel Analyses

The kernel analyses revealed several areas in which the live tortoise and carcass kernel estimations did not overlap. The pattern of non-overlaping kernels that was of most concern to us was when there were large areas where the kernels encompassed carcasses, but not live animals. The interpretation of this pattern is obvious, and troubling, these represent areas where there were likely declines in tortoise populations. This pattern occurred in half of the areas for which kernel analyses were conducted (Figures 4.19, 4.24, 4.22, 4.23). It should be noted that a few of these areas had relatively few transects (Fig. 4.22, 4.23), and that the data underlying these results come from only one year of sampling. For the West Mojave, more transect data are available from transects that were sampled to record tortoise sign, and cluster analyses of those data show similar results to the kernel analysis for 2001.

Kernel analyses for the Upper Virgin River, Chemehuevi, and Chuckwalla/Pinto Mountain DWMAs show patterns of overlap for observations of live and dead animals that were more like what would be expected of normal tortoise populations. This pattern was that carcasses should most likely occur where there are live animals.

4.1.3.4.2 Cluster Analysis

Nearest Neighbor Hierarchical Clustering to identify live tortoise and carcass clusters was performed in CrimeStat II. Test for complete spatial randomness of LDS transects in 2001-2003 and all years combined were conducted in the ArcView extension Animal Movement. Results confirmed that 2001 transects were randomly spatially distributed across the DWMA's. However, 2002 and 2003 transects proved to be spatially clustered across most DWMA's. Subsequent recommendations by this committee would eliminate this bias in future years. As a result of this bias in 2002-2003, test for spatial clustering of live and carcass observations could only be conducted 2001 data. Though we recommend that analyses such as these be conducted across the entire range of the desert torotise and in subsequent years, time limitations have prevented us from doing so in this report. However, an example is provided for the West Mojave (Fig. 4.26). Where one finds live animals one would expect to find carcass, however, were one finds carcass and no live animals there is cause for concern. This suggest recent die-offs and/or a failure to protect tortoises in these areas.

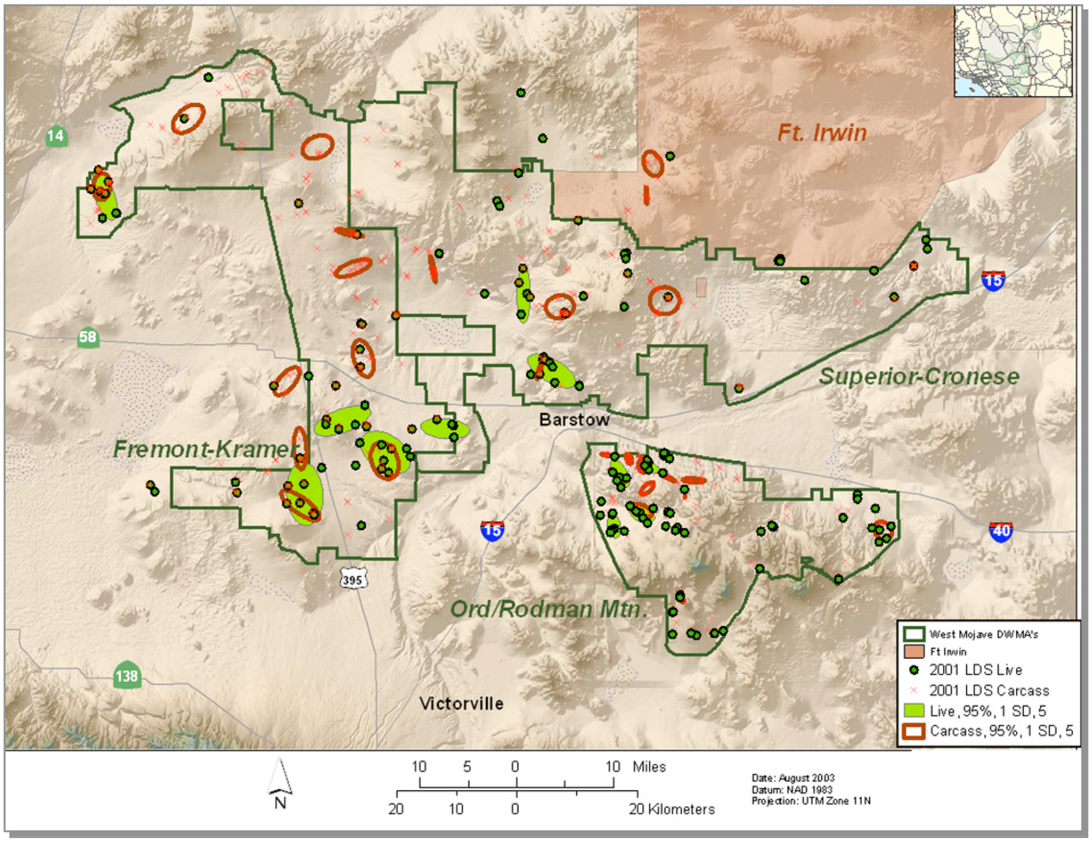


Fig. 4.26 Cluster analysis for Western Mojave. Green areas are clusters of living tortoises, and red outlines are clusters of carcasses.

4.1.3.4.3 Conditional probability of being alive analyses

4.1.3.4.3.1 Resampling Analysis

4.1.3.4.3.1.1 Resampling Statistical Analysis Methods

The transect data from the West Mojave were divided up into 18 bins, where within each bin, the transects were geographically close. The proportion of tortoises that were alive was then calculated for each bin, and a test statistic derived, which was the observed proportion alive in the bin, minus the proportion calculated from the whole data set (0.284).

The 18 observed test statistics were tested for significance using a randomization method. To produce a randomized set of data the 609 transects were randomly reallocated to the 18 bins. This was done 10,000 times. The p-value for the statistic from the ith bin was

then the proportion of times that the randomized sets of data gave a value as far or further from zero than the observed test statistic.
In addition, a 19th statistic was considered, where this is the maximum of the absolute values of the statistics for the individual bins. This then can be used for an overall test of differences between bins for all of the data.

4.1.3.4.3.1.2 Resampling Statistical Analysis Results

	Bin																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Max
Observed	0.08	-0.13	0.10	0.06	0.10	-0.28	0.29	0.03	0.05	0.09	0.01	-0.14	-0.06	0.05	-0.21	0.52	0.05	0.22	0.52
P-Value	0.452	0.242	0.467	0.295	0.467	0.002	0.008	0.752	0.539	0.086	0.850	0.042	0.559	0.432	0.074	0.001	0.535	0.085	0.004

As shown above, there are very highly significant results for bins 6, 7 and 16, and for the maximum statistic. There is also a result that is significant at the 5% level for bin 12, and a nearly significant result for bin 15.

There seems little doubt that the proportion of live tortoises does vary over the West Mojave desert.

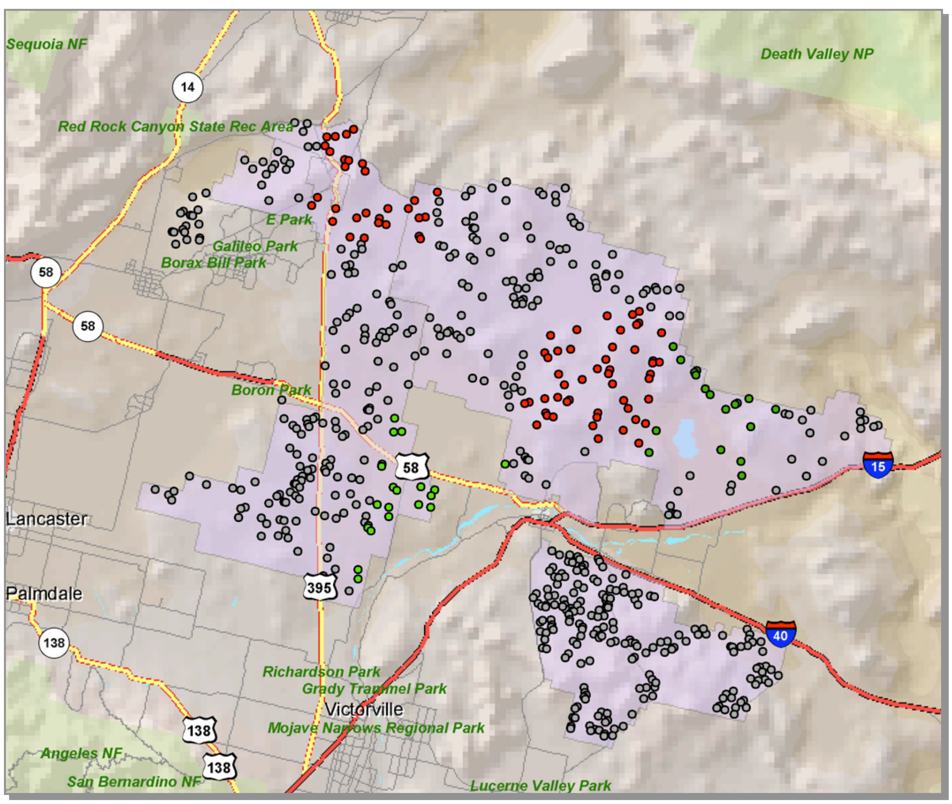


Fig. 4.27 Results from the resampling analysis - Areas depicted in red are points in bins 6 and 12, which had lower than average probabilities of live encounters, green points are bins 7 and 16, which had higher proportions of live animals. Points in all other bins are gray in color.

4.1.3.4.3.2 Logistic Regression

4.1.3.4.3.2.1 Logistic Regression

Another analysis was possible, based on logistic regression. The model considered was where the probability of a tortoise being live at a distance E km east and N km north from easting 414493 and northing 3825771 is given by

$$P(E,N) = \exp(\beta_0 + \beta_1 E + \beta_2 N + \beta_3 E.N + \beta_4 E^2 + \beta_5 N^2)/\{1 + \exp(\beta_0 + \beta_1 E + \beta_2 N + \beta_3 E.N + \beta_4 E^2 + \beta_5 N^2)\}.$$

The basic data in this case comes from the transects where live and/or dead tortoises were found. Each of these transects then provides one observation on the number of tortoises that were live in a sample of n tortoises.

It is possible that higher order polynomial terms are needed in the equation to better describe the spatial changes in the probability of a tortoise being live. This was not investigated.

4.1.3.4.3.2.2 Logistic Regression Results

The following analysis of deviance shows that the model accounts for a significant amount of the variation in the data. The mean deviance is much larger than one, indicating that part of the variation in the data is not properly accounted for. This confirms that it would be worth investigating adding higher order polynomial terms into the equation.

	df	Mean deviance	Deviance	Deviance ratio	Approx chi pr.
Regression	5	47.8	9.561	9.56	<.001
Residual	300	820.5	2.735		
Total	305	868.3	2.847		

The estimated coefficients are shown below.

	Estimate	s.e.	t(*)	t pr.
Constant	1.966	0.633	3.11	0.002
E	-0.02214	0.00506	-4.37	<.001
N	-0.02654	0.00979	-2.71	0.007
EN	0.0000791	0.0000251	3.15	0.002
E2	0.0000480	0.0000133	3.61	<.001
N2	0.0000348	0.0000427	0.82	0.414

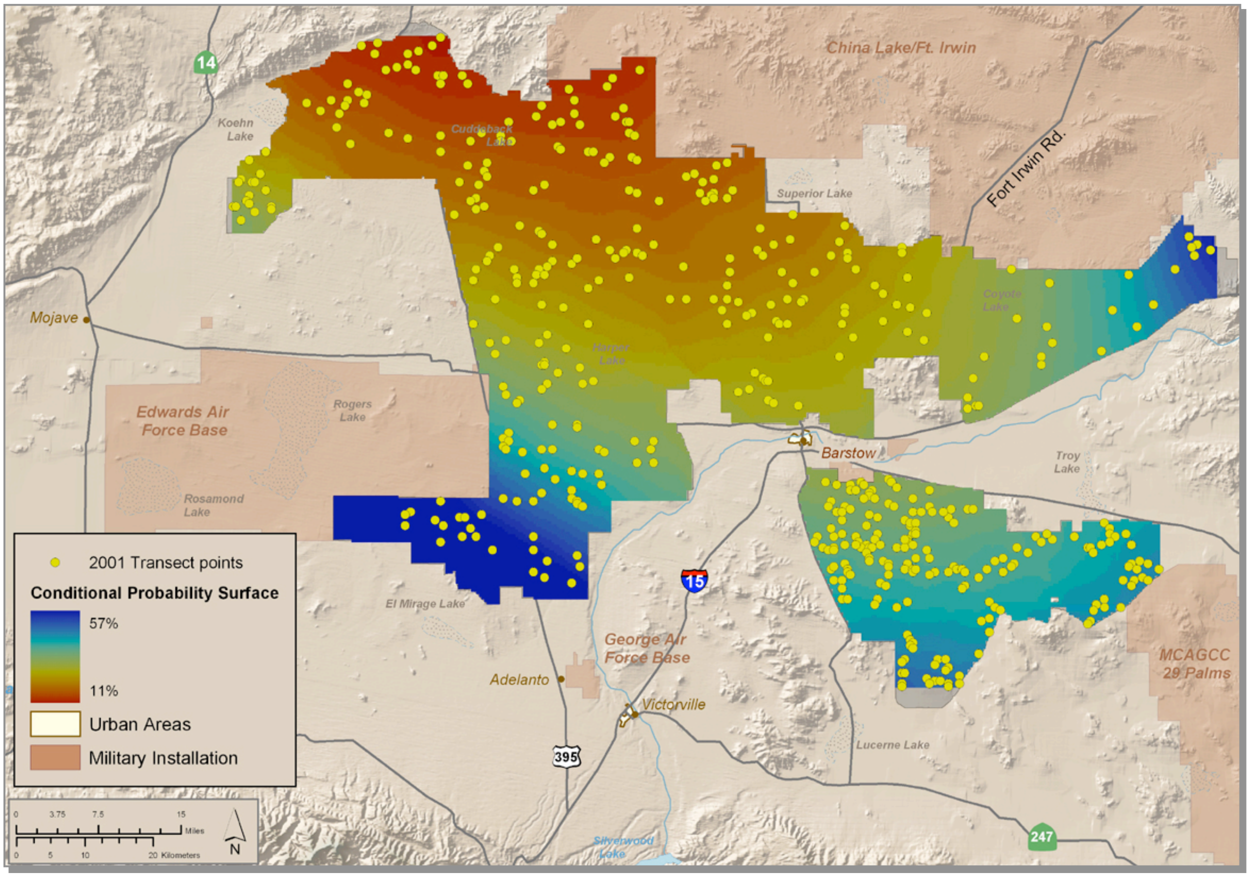


Fig. 4.28 Results from the logistic regression analysis. The color pattern depicted by the colors range from 0.1 (red) to 0.6 (Blue). Cooler colors indicate higher probabilities of encountering a live tortoise, and warmer colors indicate a lower probability.

4.1.4 Discussion

Given the data available to the committee, and the analyses for permanent study plots grouped into the current Recovery Units, and the proposed Distinct Population Segments one areas stands out from the rest of the range. The West Mojave (Recovery Unit/DPS) has experienced marked population declines over time. This was indicated in the original recovery plan and continues today. Spatial analyses of the West Mojave show areas with increased probabilities of encountering dead, rather than live animals, areas where kernel estimates for carcasses exist in the absence of live animals, and clusters of carcasses where there are no clusters of live animals, and these analyses point generally toward the same areas within the West Mojave. Together, these independent analyses, based on different sets of data, all suggest the same conclusion. There was a critical failure of management in the West Mojave Recovery Unit, and tortoise numbers are plummeting.

4.1.5 Recommendations

1. We recommend that the West Mojave Recovery Unit /DPS listing be elevated from threatened to endangered. All analyses, including that from PSP data, to transect data clustering and kernel analyses point out problems that appear to be unique to that region.

2. If permanent study plot are to continue to be surveyed then there should be some agreement among the surveying agencies to share the data for the greater good of the tortoise. Permanent Study Plots played a key role in this committee's interpretation of the current status of tortoise populations, but it is possible that some of the conclusions reached as a result of our analyses could be different if additional years of data were available. However, the trend from the West Mojave would be very unlikely to be reversed.

3. There were several recovery units and proposed distinct population segments that contained too few permanent study plots to be analyzed either with any power, or at all. If PSP sampling is to continue, it would be better if there were enough study plots to represent the different scales of management areas. As a study plot is in itself only one sample, and not representative of an entire area, it would be more beneficial to have several plots within each area upon which future analyses are to be conducted, for example the DPS, or even DWMAs within DPSs.

4.2 Status and Trends of Recovery Plan Implementation

Although we specifically address threats and impacts to tortoises in the next section, Fig. 4.29 graphically illustrates the number of perceived threats originally identified in the Recovery Plan for each DWMA. The Plan also identified specific management actions to address these threats, the numbers of which are similarly illustrated in Fig. 4.30. However, an analysis of recovery plan implementation based on written surveys in 2003 of land and wildlife management agencies indicates that implementation has been uneven relative to recommended management (Fig. 4.30). Note that these surveys did not directly correspond to the specific actions recommended in each DWMA, but were general questionnaires on what management activities had been carried out by each agency. Therefore, we intend the following discussion to represent a first-cut review of the general status of recovery plan implementation without delving into a comprehensive analysis of each recommendation in the Plan.

Of particular note is the apparent lack of implementation within the western Mojave Desert (Fig. 4.30), even though the Recovery Plan called for a relatively high degree of management in this area (Fig. 4.30, Table 4.3). In fact, an average of 36% (n = 12; Coyote Springs Valley is combined with Mormon Mesa and Joshua Tree not included) of the management recommendations per DWMA had not been implemented as of 2003, ranging from 100% (at least partial) implementation at Upper Virgin River to only 32% implementation at Ord-Rodman (Table 4.3). Only 38% of recommended management actions have been implemented overall in the Western Mojave Recovery Unit, and tortoise populations in this region have shown the most dramatic declines (this report).

Another important point of this analysis is that tortoise populations may persist in the presence of a relatively high degree of threats. For example, the Upper Virgin River Recovery Unit is faced with numerous threats (Figure 4.29), at least partially due to its small size. However, relatively intensive management (Figure 4.30, Table 4.3) has apparently prevented impacts to the tortoise population by addressing various, potentially interacting threats identified in 1994. Still lacking is the scientific framework to resolve the degree to which specific management actions mitigated specific potential impacts in the Upper Virgin River.

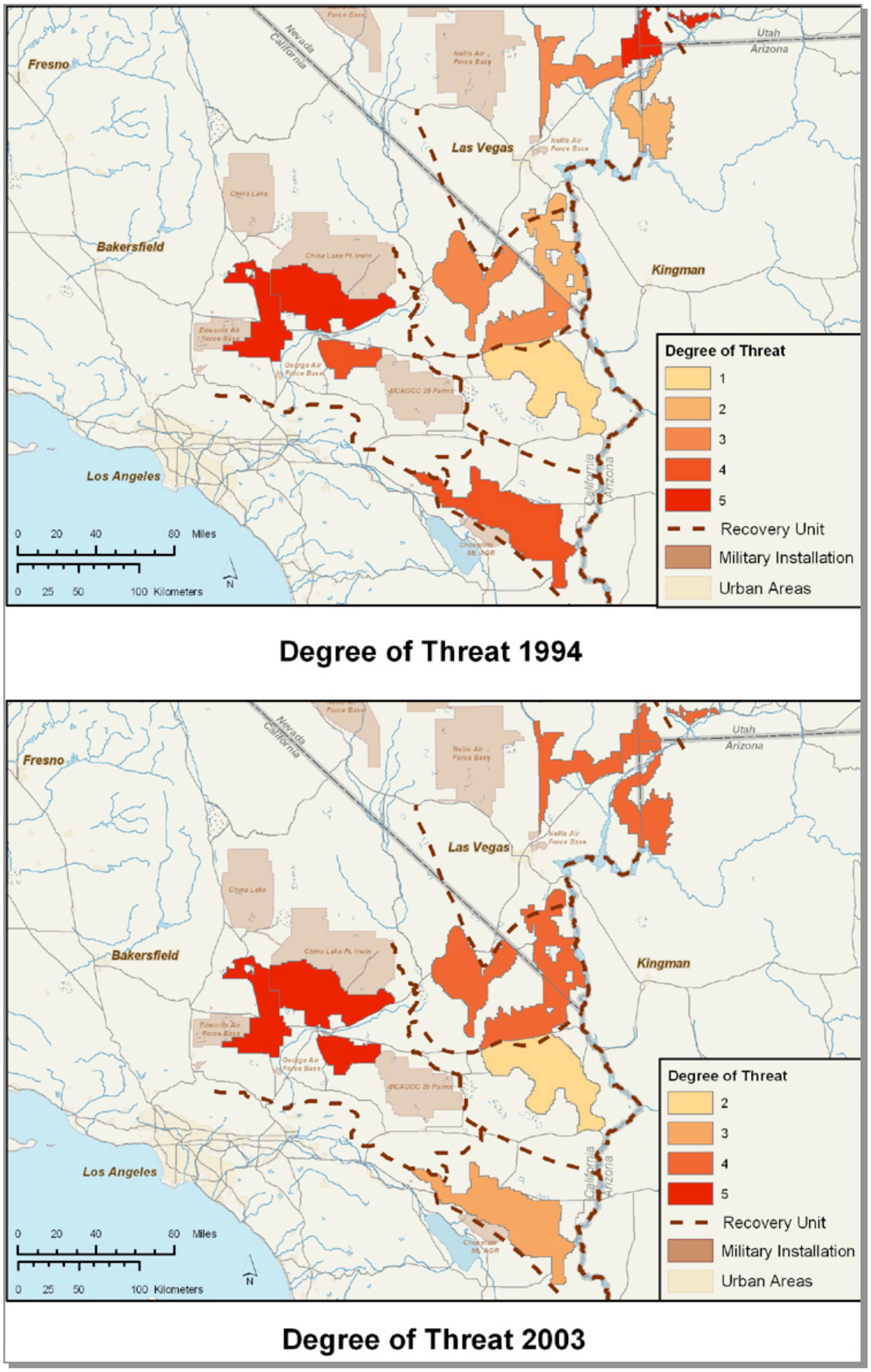


Fig. 4.29 Degree of threats to desert tortoises in each critical habitat unit (i.e., DWMA), as identified in the 1994 Recovery Plan.

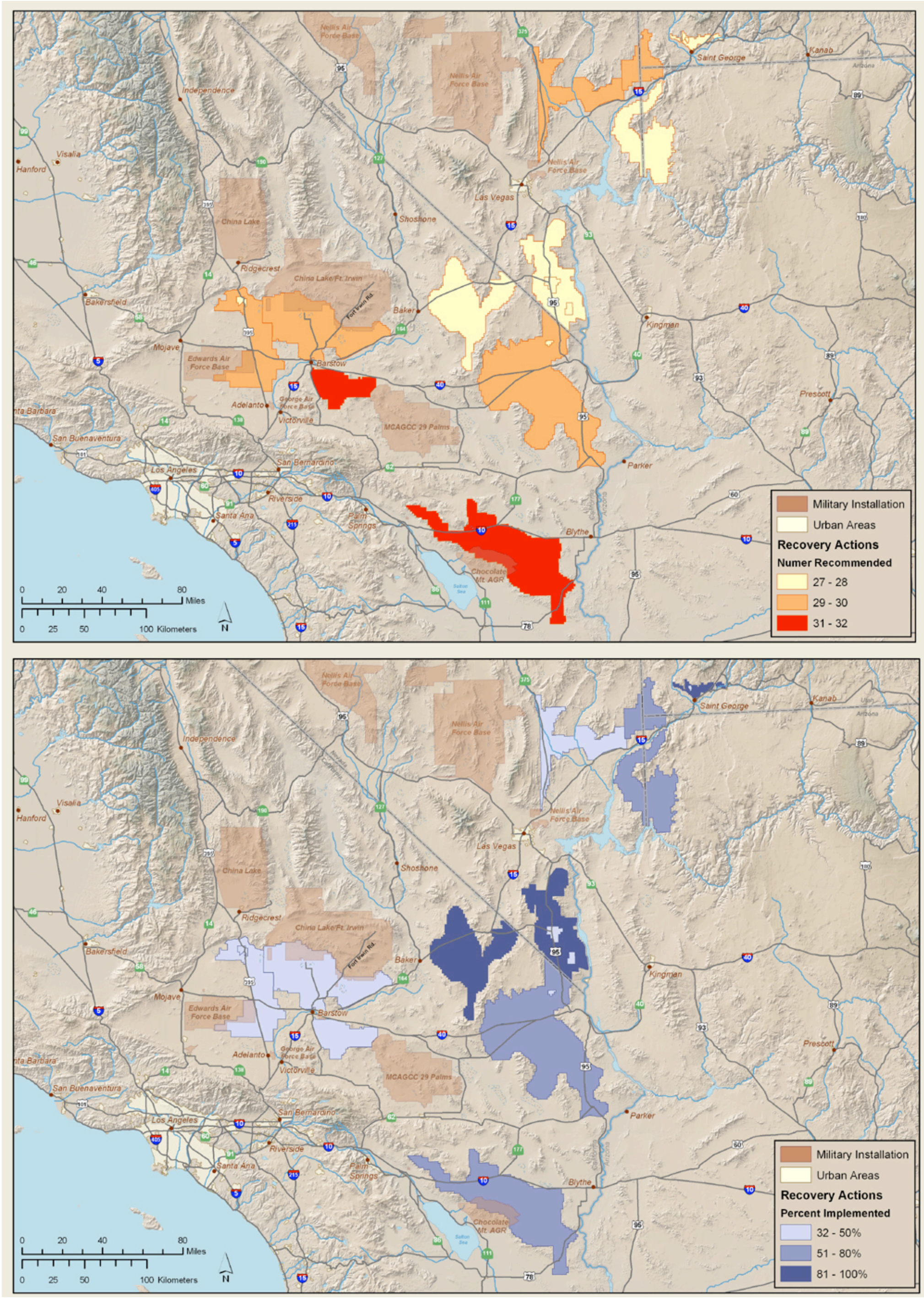


Fig. 4.30 Relative numbers of management actions recommended for each critical habitat unit (i.e., DWMA) in the 1994 recovery plan and in 2003.